Sustainability and social justice dimension indicators for applied renewable energy research: A responsible approach proposal

Ruth Carbajo, Luisa F. Cabeza*

GREiA Research Group, INSPIRES Research Centre, University of Lleida, Pere de Cabrera s/n, 25001-Lleida, Spain

* Corresponding author: lcabeza@diei.udl.cat

Abstract

Aspects of sustainability and social justice deserve special attention in the research and innovation landscape in Europe. In this vein, the inclusion of innovative research and innovation policies, such as Responsible Research and Innovation, devoted to mainstream social outcomes, to deploy democratic governance of science, and to drive innovation into a direction that is ethically acceptable, societally desirable and sustainable are noteworthy. However, substantial efforts are required when it comes to integrate the interactions between renewable energy research and energy and climate policies within responsible approaches. In order to adapt responsible research and innovation approach for the purpose of building an alternative context and assessment approach for sustainable transitions, this paper presents a review of approaches around sustainability and social justice dimensions. The thresholds of this endeavour are detailed in terms of the challenges for the integration, the identification of the inhibitors and facilitators of policy integration and the proposal of the levels for a methodology for this integration. The results show that the different readings and understanding of the contexts and dimensions and the existence of knowledge gaps between policy targets and the outcomes of research and innovation can be considered inhibitors for the integration. In contrast the interlinks between dimensional concepts, backgrounds and rationales appear as facilitators. The innovative contribution of this paper is focused on the contextualization of the dimensions through the use of socio-technical and multi/inter/trans and cross-disciplinary approaches. The authors conclude that the process of introducing a more holistic and alternative approach opens the re-envision of policy elements. Moreover, RRI offers an innovative perspective to the transition approach as well as tools for decision-making and policy processes assessment, in an arena where constant innovation is taking place and new structures, processes and metrics are necessary to guide this process.

Keywords: Responsible research and innovation (RRI); Responsibility; Sustainability; Social justice; Policy integration; Sustainability assestment frameworks

1. Introduction

Aspects of sustainability and social justice, along with outcomes related with science education, engagement, gender, ethics, open access/open science, and governance are the core of Responsible Research and Innovation (RRI) approach which has been the expression of the political guidelines for the European Commission regarding to science and society interactions. These guidelines, aligned with global social, economic, and environmental challenges have the eagerness to achieve excellent science, competitive industry and a better society [1–3]. Moreover these aspects are comprised in Europe 2020 strategy, which includes headline targets in employment, research and development, climate/energy, social inclusion, and poverty reduction [4]. Since, the rationale of the Europe 2020 strategy is to address and overcome the shortcomings of the current growth model in order to achieve smart, sustainable and inclusive growth with a clear eye for fairness and democratic change, policy strategies including socio-technical integration and multi, inter- and trans-disciplinary collaborative research strategies have been tested and developed for the achievement of these goals within policy initiatives and national and European programmes. Europe's commitment to RRI has led to substantial societal and scientific benefits [5–8] allowing to settle approaches such as social innovation [9] and open innovation [10], which becomes visible through collaborative EU projects that have brought together diverse sets of actors to co-create and implement common agendas through citizen science, science communication and public engagement actions. Moreover, these initiatives have built an evidence base about this alternative science-society interactions [11]. Insigths of the responsible approach in the proposals for post 2020 EU R&I programs [12] and policy strategies although it is still to be settled, can be found in the adoption of a mission-oriented, impact focused approach to global challenges which, moreover, seeks to mobilize and involve citizens and capture and better communicate the impacts [13,14].

Responsible research and innovation as concept, approach, or policy [15] is located under the responsible innovation approach, which is built on governance, socio-technical integration of innovation, and technology assessments methods [16]. Within responsible innovation it is essential to reflect on social and environmental needs and any innovation process has to be guided by improvements in anticipation of collateral effects and consequences of technology [17,18]. This influence makes that among other goals, responsible research and innovation aims at taking ethical and societal concerns from the beginning if the innovation practice giving place to a process reformulation [19,20] and the achievement of a democratization of innovation through social, open, participatory, and crowdsourced research strategies [21]. Moreover, RRI comprises the inclusion of upstreaming deliberative forms of governance such as stakeholder and public engagement integration in the research and innovation process [22]. All of this in order to help to

realise a collective responsibility to control and drive innovation into a direction that is ethically acceptable, societally desirable, and sustainable [19].

The theoretical backgrounds of RRI are based on science, technology and society studies (STS), technology assessment (TA) approaches [15], and in a combinations among those. Moreover, under the socio-technical integration approach, RRI seeks to the explicit incorporation of activities devoted to broader social aspects into scientific production [23] along with integration of alternative experts, methods and perspectives into science and technology disciplines [24,25]. It thrives from science, technology and innovation (STI) policy frameworks devoted to set the goals for socio-technical systems reflecting a range of more inclusive ideas about social welfare and the transition to more sustainable outcomes [16].

At operational level, RRI policy entails the fulfilment of two main fundamental missions: the development of specific research agendas and the reformulation of the innovation process. The process reformulation is proposed to be carried out through the definition of attributes that the innovation needs to fulfil to be considered responsible. These attributes came from responsible innovation approach and are, anticipation, reflexivity, inclusion and deliberation, and responsiveness [1] or anticipation, reflexion, engagement, and action [26], depending on the approaches. These achievable dimensions or capabilities were explored from the fields of the social sciences and humanities such as the body of works of policy studies, cross-cutting policy-making, decision-making or holistic government as well as anticipatory governance [27]. In contrast keys for the agendas development are science education, open access, engagement, ethics, gender, and governance; which were updated with two more areas of relevance, social justice and sustainability, included in RRI as an expression of the policy goals, since they were the backbone of the Europe 2020 strategy [28].

At a time when decision-making is facing increasing complexity as a result of various concurrent trends driving this process, policy integration, in terms of the management of cross-cutting issues that transcend the boundaries of established policy, is considered crucial to achieve sustainable development, especially in environmental disciplines [29] Regarding to the trends under sustainability development towards sustainable transitions; the globalization and greater centralization coexist with the fragmentation and decentralization of decision-making spheres as well as the number of actors involved in policy process.

In this vein, while transformative change and RRI approaches provide a scenario of integration and benefits, at practical level, researchers and policy makers face obstacles in understanding the interactions of the impacts of environmental, economic and social features in policies [30].

Moreover, the inclusion of the label of responsibility, it does nothing but adding complexity to this process. This is especially remarkable in the case of the interactions between research and energy and climate policies as it happens in the case of renewable energy research and innovations [31].

The policy integration process requires from shifting from a theoretical discussion to the operational level of a concept and from the ability to identify inhibitors and facilitators of the process. This first endeavour can be achieved by different paths: characterising and measuring the different aspects of the concept, or through boarding the concept to embrace different perspectives and trends.

The path to measure the different aspect of the concepts has been widely reported in the energy research dealing with social aspects related literature for example for the case of social acceptance [32-34].In this vein, selecting this path requires from accepting that since the impact of the implemented process cannot be determined with any degree of confidence if there is no knowledge about the context within which they have taken place, an understanding of the context is vital in terms of replicating the intervention. The context must be considered as part of the evaluation and is key when it comes to uncovering the circumstances in which, and the reasons why, a particular intervention works. In contrast, in the case of considering the path of broadening the concepts, which is the path that is proposed in the transitions approach, this requires a concept reformulation. Under this approach, the proposals are not anchored in the concepts which are no longer seen as a goals, but rather how the system needs to be changed to contribute to progress along the path to such goals. An example of this approach can be found in the case of sustainability dimension, in terms of not to sustain but to change [35]. Moreover, when the process of broadening of the concepts is considered, not only a diversity of approaches is taken into account, but the different inputs, new trends and perspectives that, over time, the frameworks integrate and embody [36].

Both the measurement of the differences aspects of a concept and the alternative of broadening the concepts entails the consideration that the approaches intrinsically, are affected not only for the meanings (semantics), but for the scope where action is located [37]. From this consideration steams the idea that the definitions can transit between the form of normative judgments, such as goals and targets, to the form of semantic or philosophical clarification[38].In this sense, for the fields of energy research and policy, the measurement of the different aspects of a concept considers rationales such as the responsibility to assume the effects and minimize environmental degradation and climate change; the recognition of the importance of more people-centric approaches for energy use; the understanding the human dimensions of energy as promise of

generating valuable insights about energy culture and the process of individuals sharing resources with those who have less [39]; among others. In addition, broadening the concepts resulted in the inclusion of alternative rationales such as the effective mechanisms for transforming how people, organizations and societies use of energy in terms of historical and future shifts in energy practices [40] and the processes of variation of energy-use patterns [41].

Most of these approaches are aligned with the socio-technical idea of archive responsible use of resources (achieving responsibility) to ensure the balance between economic growth, environmental care, and social welfare [42], which can be considered as one of the most used theoretical approach.Moreover, in recent times, alternative approaches dealing with responsibility issues from the justice point of view have increased [43].

The second challenge of the policy integration lays in the identification inhibitors and facilitators of the process which arise when it comes to transcending from policy to practice. In this vein, an example of inhibitor of responsible policy deployment is the need of policy contextualization in terms of specific disciplines. RRI is a research policy devised to be applied in any scientific discipline, however the application and the rendering of its drivers (key elements to develop specific agendas and process dimensions) may result unclear depending on each research field. In addition, since RRI policy at assessment level is still under development, both due to the lack of methodologies and indicators proposals, monitoring the impacts of its implementation, entails difficulties. As matter of fact, RRI impacts assessment is often considered one of the most important barriers to overcome for an overall policy integration [44]. Other factors no less important are related with the absence of primary data to measure the impacts and arrange indicators, the lack of frameworks for policy contextualization [6] as well as the absence of consensus regarding to which methodology to choose.

In contrast, one of the strengths of responsible research and innovation and a facilitator for policy integration are the multiple connections between proposed dimensions that affects both agenda setting and process reformulation. This joint process nature is often considered a burden that compromise the policy contextualization. The further development of methodologies and assessments proposals, however, as shown in Figure 1, these multiple interlinks are the core for a policy integration construction [31].

This connection affects at context and policy level. At context level, the interlinks affects the overall evolution of the meanings and understandings along the approaches, which can be considered also a facilitator of the integration and it will be discussed along this paper. At policy level, in contrast, sustainability and social justice are included in RRI as an expression of the

policy goals and are interconnected and related to some extent with aspects of inclusion. Moreover, they share the aim of promoting good governance. Furthermore, as show in Figure 1, both inclusion and governance are the core dimensions since they provide the elements from where the rest of the dimensions and keys are generated. The search of governance is going to be embedded in the search of (good) governance which includes the development of keys or policy agendas and the consideration of ethical aspects and societal needs; along with the statement of research agendas including innovative methodologies and the alternative impacts measurement systems .

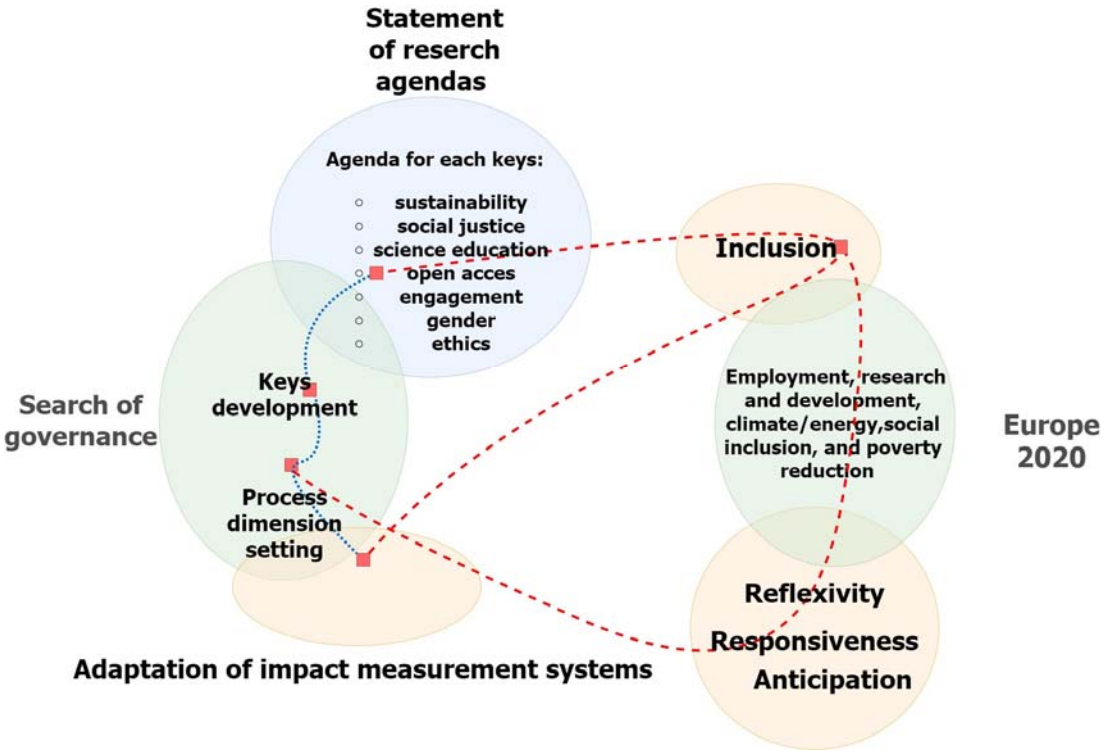

Figure 1. The insights of these connexions linking key and dimensions for RRI and Europe 2020 strategy goals in terms of agenda setting and process reformulation.

In addition, responsible research and innovation shares elements with the innovation frame of transformative change, which was proposed after the traditional frames of the innovation for growth and national systems of innovation [45]. This fact can be considered as an stregth for policy integration, since transformative change is characterized by being linked to contemporary social and environmental challenges [16]. From this approach, transition policy approach emerged, aiming to address complex policy challenges of a long-term nature, such as sustainable transitions. The proposal to address the challenges are for example the creation of spaces with the purpose of transforming general policy goals into concrete visions, which in turn are used to develop possible transition paths to how to connect the present with the future [45].

Moreover, also shares elements with social justice theories, in terms of address the inclusion dimension. Social justice theories include the logics of distributive justice, procedural justice, cosmopolitan justice, and justice as recognition [46]. In this vein, distributive justice draws the aspects such as distribution of goods (proper mode of distribution, and which entities are in charge of the distribution addressing distributional justice) and procedural justice is concern with how decisions are made in the pursuit of social goals, or who is involved and has influence in decision-making. Moreover, the sub elements of procedural justice are the access to information; participation in decision-making; impartiality from decision-makers; and access to legal processes for achieving compensations. In the case of modern-cosmopolitan justice it addresses the societal considerations in terms of universal justice application and collective morality assessment as well as individual dimensions of the justice [47].

For the case of renewable energy research and innovations, the special attention received by sustainability and social justice dimensions is not new. In this vein, before the transitions approach was widely considered for the inclusion of social aspects, these dimensions were approached through ethics assessments [48] and energy related social science frameworks [49,50]. In these terms, sustainability imprints were linked with three traditional sustainability dimensions, namely, ecological, economic, and social sustainability. In addition, the social justice dimensions were related with the justice of procedures and the distribution of goods and resources [43]. Moreover, the shifts in perspectives from a focus on economic development towards a view of growth in terms of sustainable development resulted in two innovations. The first one is the incursion of more inclusive considerations for both sustainability and social justice as individual dimensions. and the second one is the introduction of approaches to consider the mutual feedback between them, such as the social sustainability approach and the energy justice body of works.

The social sustainability approach [51], which covers interactions between economy, society and ecosystems and social justice is an example of this inclusive considerations. This approach, reinforce the sustainability dimension in terms of clean, reliable, and affordable (sustainable) energy, and link it critically with achieving inclusive, low-emissions growth and development and mitigate climate change. Under this consideration, sustainable energy can influence human progress, creating jobs and economic competitiveness, can empower women, can lead to new global markets for goods and services, can alter regional energy trades, and can help ensuring that environmental impacts of economic development are minimized [52]. In addition, the energy justice proposal [53] was designed to deal with controversy in energy projects [54] drawing on the justice-related claims embedded in both the legal system, and public discourse. It is related with environmental justice in terms of being focused in the distribution of environmental hazards and access to natural resources including protection from burdens, meaningful involvement in

decisions, and fair treatment in access to the benefits [55]. As a framework, it emerged as a new crosscutting social science research topic which seeks to apply justice principles to energy policy, energy production and systems, energy consumption, energy activism, energy security, and climate change [43]. The justice-related attributes were included in this body of works, through the social justice theories approach. This approach takes into account the imprints of each dimension in regards to energy related rationales. Such rationales are the distribution of material outcomes, public goods, resources or wealth and public harms such as pollution or poverty [56].

Sustainability and social justice rationales can be found also, in several related approaches such as green, eco, environmental and sustainable innovation [57], which, moreover, overlap with responsible innovation at concept level [17]. In these terms, sustainable innovations are initiated in response to a grand societal challenges such as climate change [58], which is additionally, one of the most dominant public debates related to the role of science in society of the last decade. Under this approach, sustainability and social justice imprints can be found in the demand for innovative, alternative and sustainable technologies for climate change mitigation ; in the elements of research and policy such as engagement of public with science; in the development of new formats for public participation in decision-making; and in the deals that results from the raising of questions related to governance of science, the trust in scientists and expertise, and the participation in funding of research and development [5].

In contrast with the overacting frameworks dealing with sustainability and social justice isolated dimensions, sustainability assessment body of works are specific approaches characterized by their ability to discern from the concepts, dimensions, goals and synergies. Moreover, sustainability assessment are approaches that were designated to develop sustainability targets for both science and policy-based issues focused in linking science to actions [36]. These actions, which can be policies, planning, or products, needed to be evaluated in order to define the degree of sustainability through the assessment process .SA backgrounds are based on impact assessment tradition and policy support methodologies with sustainable development models as the oldest representatives [59]. The utility of sustainable development models, since they are applications for practical assessment of progress towards sustainability, within the system approach, lays on the fact that they consider sustainable development and hence sustainability as a property of viable system. If a system is viable it will be sustainable [38]. The continuous re-envision of models constitute one of the most important insights of SA either through the integration of trends either through the adaptation of the frameworks to new needs. In fact, recent revisions of sustainable assessment frameworks intended to develop policy support tools and recommendations to carry out accurate and effective process of assessment are aligned with responsibility policy insights. In this vein, an example of the trends that have been incuded in these frameworks are the

emergence of post-normal science [60]; the increasing demand for policy-relevant science;the changes in the development of monitoring methodologies; the changes in data collection and data sharing mechanisms in terms of citizens particpations; and the civil society initiatives [36]. Moreover, the integration of concepts such as democracy related with public legitimacy and the seeks to foresight changes to political decision-making in terms of the integration of socio-ecological systems to foster evidence and accountability in dealing with related risks are examples of the adapatation to a new necesities.

In contrast with RRI dimensional considerations, sustainable assessment frameworks comprise various dimensions that can be grouped in two general divisions: methodological aspects (contexts, discourses, etc.) and the decision-making context more devoted to process assessment. Methodological aspects generally cover the interaction between economy, society and ecosystems in terms of social sustainability and social justice. the decision making context comprise, elements such as stakeholders. Despite the differences, the sustainability assessment methodological aspects and the decision-making context can be aligned with two RRI missions, the process re-envision and the agenda setting. In addition, the contributions coming from sustainable assessment approaches, such as the Bellagio STAMP principles [61], can be taken into account to contextualize sustainability in terms of a process dimension envision, as it will be developed in further sections.

Before going into the subject matter of this paper in more detail a few clarifications may be in order. When it comes to implement RRI approach, both attributes and key elements are considered to be the *conceptual* dimensions of RRI [62]. Moreover, in recent literature regarding to this topic, both key and dimensions words have often been used indistinctly. Furthermore, often assessment methods such as sustainability assessment frameworks, consider the dimensions, as the elements of the process, which needs to be re-envisioned. Under this approach, sustainability for example is a goal and a concept but not a dimension. In this sense, for the purpose of this paper, elements for the agendas development, namely science education, open access, engagement, ethics, gender, and governance, social justice and sustainability are going to be considered *keys* or elements and the process reformulation attributes, namely, anticipation, reflexivity, inclusion and deliberation, and responsiveness, are going to be considered *achievable dimensions*. Moreover, the distinction between dimensions entailing responsible attributes and sustainability assessments frameworks *process* dimensions will be carried out in the sections where these contributions of these approaches is described. Furthermore, while RRI is focused in two missions, the development of methodological proposals in literature has been focused mainly in the process re-envision in terms of conceptual dimension assessments and based in responsible innovation approaches [17].

In order to stablish the methodological basis to arrange a policy integration within responsible research and innovation (RRI) approach, this paper reviews and compares different methodological approached for sustainability and social justice dimensions. The hypothesis for this proposal is related with the feasibility to encompass the contributions of different policy approaches taking into account the corollary that they share a general vision towards achieve, among others goals, the reformulation of innovation process and the re-envision of agenda setting, as well as the paradigm change in decision making process. In this sense, bringing about more conceptual clarity to both dimensions through the generation of a theoretical framework is the first objective of the paper. For this reason, in the first part of this review, the clear understandings of the implications of the dimensions in the different contexts and the consideration that the approaches are affected not only by the meanings are the two aspects that are going to act as the boundary conditions for the development of the policy integration.

The first block of the theoretical framework is going to be built in the insights obtained from the review of the overarching approaches under socio-technical transitions. In addition, characterising the different aspects of the concept is going to be built upon the state-of-the-art, where the findings are going to be separated in terms of conceptual frameworks and operational frameworks. In these terms, conceptual frameworks are going to be considered the theories shaping the context and the operational frameworks are going to be considered the methods that provide tools for the construction of proposals. For example, sustainable development approaches and the energy related social sciences body of works are going to be considered conceptual frameworks, and sustainability assessment frameworks body of works are going to be considered operational frameworks.

Moreover, this paper introduces also two methodological levels of context and assessments. This entails gathering the inputs regarding the context for both sustainability and social justice dimensions, and gathering the impacts in its assessment.

Steps for the construction of theoretical frameworks are shown in Figure 2.

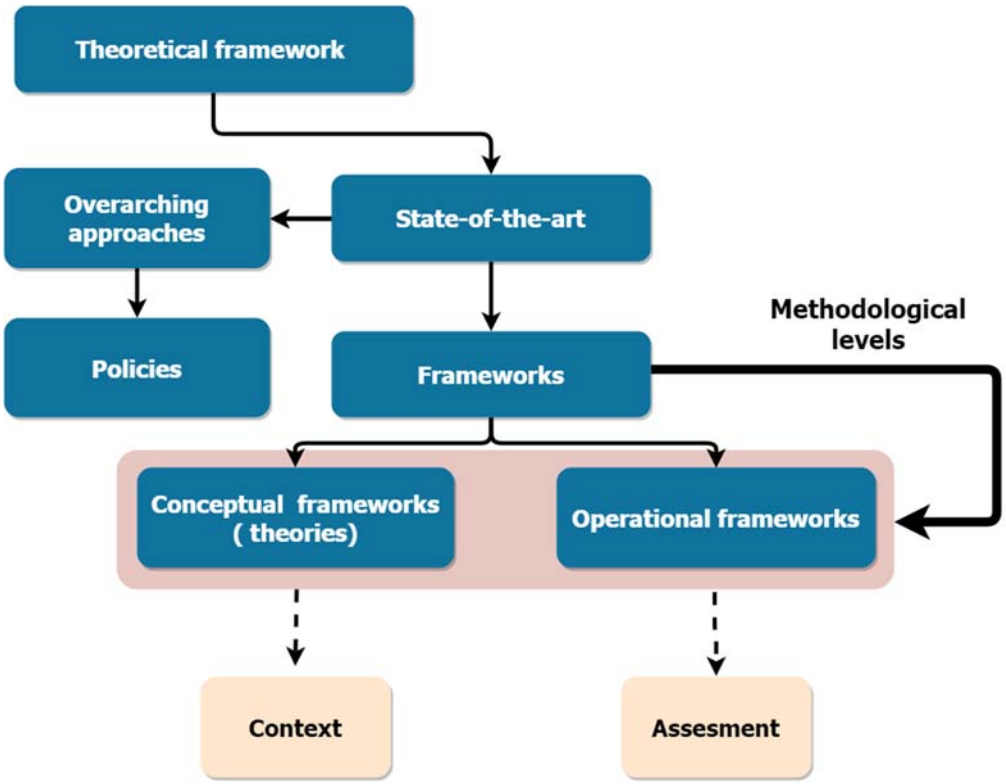

Figure 2. Policy integration theoretical framework.

Even if the RRI approach can provide a scenario to integrate the interactions between renewable energy research and energy and climate policies within the sustainable transition, the identification of inhibitors and facilitators of the process is considered a challenge. The enlightenment of the wealth of material concerning facilitators and inhibitors of policy integration, assisted by the prior theoretical framework comprise the second objective of this paper.

This paper is structured as follows. The remaining of the paper, headed by Section 2, starts with the description of the RRI dimensions, where process and agenda setting elements are described; followed by the technology assessment for responsible approach insights description; followed by the overview of the assessment elements and process towards indicators and a brief insight of the approach to socio-technical integration. Next, in Section 3, sustainability assessment frameworks are described in terms of their overview and backgrounds. This section is organised based on a system approach and, later on, based on the contribution to a policy-oriented assessment. In Section 4, the methodological imprints of RRI and sustainability assessment are described. Regarding RRI, this section reviews the outcome based models and the proposals for process dimension assessment. Moreover, regarding sustainability assessments, this section shows a review of the levels of integration and the construction of the dimensions. Following,

Section 5 comprises the description of the reviewed frameworks contributions in terms of the proposed methodological levels, where the differences and similarities as well as the proposals to contextualize and evaluate sustainability and social justice dimensions are presented. Section 6 comprises the discussion addressing the challenges of the integration, the identification of inhibitors and facilitators, and the applicability and pertinence of the proposed levels to achieve a successful policy integration in the view of this methodological basis. Finally, the conclusions section (Section 7) ends this paper.

It is important to point out that the present paper is part of a broader study aiming to explore the implementation of the (RRI) approach in renewable energy research and innovations. This endeavour entails the construction of a theoretical and methodological approach with a robust level which is the subject of this paper and the performance of the validation of the proposed methodology followed by the application and analysis of case studies, which will be the subject of future works.

The innovative contribution of this work lays in the construction of a robust and interdisciplinary methodological basis composed by a theoretical framework and methodological levels with the intention of illuminate the integration of responsible approach and RRI policy for sustainability and social justice dimensions. In this vein, the importance of introducing a more holistic approach between social sciences and technological implementations supported by scientific data and experiments, which shall be emphasized in future studies, opens the possibility of the re-envision of the policy elements under transition approach. Moreover, this proposal, contributes to the integration of the RRI policy taking into account the development of agenda setting for sustainability and social justice dimensions, an option that has not been explored in literature. Furthermore, the consideration of the synergies between the two missions of RRI along with the liaisons between conceptual dimensions and keys, represented in this paper by sustainability and social justice and the inclusion and governance are considered.

2. Responsible research and innovation (RRI) policy

2.1. Process dimension and agenda setting

The responsible framework comprises a wide umbrella of concepts connecting different aspects of the relationship between R&I and society. Among others, the evaluation of technology outcomes and options in terms of moral values and the participation of stakeholders in innovation processes, as mentioned before. As a concept, RRI was put forward by the European Commission

as a key element of the Horizon 2020 programme, in which the trifold ambition of excellent science, competitive industry and a better society calls for a comprehensive research and innovation governance framework. Moreover, under socio-technical integration approaches it has been considered a policy integration example where responsible innovation enacts as a transition approach, focused on achieving democratic and anticipatory governance [1].

RRI entails the achievement of two main objectives that are intertwined: the specific research agendas development along with innovation process reformulation, as mentioned in the introduction. Both elements for agenda setting and process re-envision, namely conceptual and key dimensions, emerge from the integration of ethical aspects and societal needs which are generalizable to all scientific disciplines [1] and from the engagement with a set of aspects or even values for practices related with outcomes and options evaluations. These aspects, which are often framed under the consideration of norms, laying under the normative sphere, can be materialized as moral values, including among others, wellbeing, justice, equality, privacy, autonomy, safety, security, sustainability, accountability, democracy, and efficiency [10]. Moreover, since the normative function of the values, entails the capability to provide direction through visions linked to goals, this entails that the values they are transformed and coded in formal agreements, treaties, and declarations. Furthermore, these aspects can be visible not in the form of values but as habits and traditions, which represent individual basic knowledge and can be understood as what others do and what others think that they should be doing [40].

Dimensionally, the drivers of the integration of the ethical aspects or the achievable dimensions of anticipation, reflexivity, inclusion and deliberation, and responsiveness are the elements defined to intend to align research and innovation outcomes with values and norms. Moreover, the arrangement of responsibility assessment of both outcomes and process requirements implies, the consideration of the formulation of the entire process of research and innovation, which is expected to undertake from early stage of research and development to production and distribution, placing more weight on the social approach of techno-economic impacts such as valorisation, employment and competitiveness [10].

In contrast sustainability and social justice as key dimensions of RRI emerged due to the combination of the objectives of responsible approach that can be found in foundational definition of RRI, in terms of re-envisioning the process as a *transparent, interactive process by which societal actors and innovators become mutually responsive to each other with the view of achieving (ethical) acceptability, sustainability and societal desirability* [63]. Moreover, in the case of the integration of policy agendas, they arise from the European policy recommendations at the most general level, namely, The Charter of Fundamental Rights. These recommendations

include political guidelines for jobs and growth based in fairness and democratic change, specific to Europe 2020 strategy of smart, inclusive and sustainable growth, and are targeted to the areas of employment, research and development, climate/energy, social inclusion, and poverty reduction.

2.2. Technology assessment for responsible approach

As mentioned before, RRI backgrounds are based on science, technology and society studies (STS) and on the technology assessment (TA) approaches. They constitute the core of RRI in terms of methodological principles and policy support strategies. The imprints of this background affect both innovation process re-formulation and the specific research agendas development since they are related to the anticipation of the future use of technologies, the respective societal impact, and the reduction of the uncertainty of this innovation. Moreover, the methodologies comprising TA can be considered an operational element to achieve RRI goals [31]. Technology assessment methods in RRI combine traditional technology assessment (TA) aspects and alternative approaches such as constructive technology assessment (CTA), technology foresight, and midstream modulation. Traditional TA comprises the risk assessment approach which considerers the assessment of the potential impact of technological advance. In contrast, alternative approaches consider the idea that the technological innovation and social innovation must be considered a due process. In this vein, for example, constructive technology assessment (CTA) [64] addresses social issues mainly in the early stages of the innovation process giving place the process to be reformulated and redirected depending on the reported feedbak of the construction of the technology. In contrast, technology foresight entails processes by which researchers use methods to forecast the various types of impacts that technology will have on future societies in order to allow decisions to be made to promote desirable outcomes [2]. In midstream modulation researchers modulate their innovation decisions into opportunities, considerations, alternatives, and outcomes in collaboration with social science and humanities scientists [65].

Within EU policy, RRI is as a cross cutting issue in Europe 2020 strategy together with the open innovation. Besides, RRI comprises also the integration of other socio-technical approaches in the technology assessment process, such as social innovation [66] and demand oriented technology assessment [67]. The use of alternative technology assessment applied to energy research, since is out of the scope of this paper, was used for the case of large infrastructures in terms of constructive technology assessment CTA [68] and value sensitive design [69].

2.3. RRI impacts: Process towards indicators

The process for monitoring RRI, in terms of the outcome variables considered impacts, is affected by uncertainties that jeopardize both process dimension and agenda setting. These uncertainties are related with two main questions: the fact that RRI, as a policy principle, is under a consolidation process (so the construction of robust models and accurate indicators has been underdeveloped), and the existence of a knowledge gap between the policy headline targets (measured at a societal level of aggregation) and the performance indicators for research and development [7]. The effects of these questions are, for example, the absence of sustainability and social justice in European RRI concrete indicator proposals such as EU Indicators for promoting and monitoring Responsible Research and Innovation [28].In this vein, non-official metrics and indicators or methodological specifications for indicator selection are recommended, besides from the recommendations of the European Commission funded project called 'Monitoring the Evolution and Benefits of RRI' (MoRRI) [7].Regarding to this, since, both dimensions are mostly concerned with the headline target for R&I in the EU, an adaptation of policy recommendations such as EU indicators used for promoting and monitoring RRI and indicators of the EU Sustainable Development Strategy (EU SDS) [70] can be drawn.

In the case of the knowledge gap, it is reified since RRI, it is intended to be operationalized through the implementation of the proposed conceptual dimensions in both process re-envision and agenda setting process. In this vein, even if these dimensions are related with the headline targets of smart, sustainable and inclusive growth mentioned guidelines, the accurate indicators development, cannot be obtained enquiring directly: to what extent does a research field, a research programme or an RRI initiative contribute to these goals, and how can this process be assessed and monitored [6].

Moreover, this knowledge gap affects heavily the implementation of research policies being considered one of the most important burdens for the development of accurate indicators, since the policy implementation entails not only the translation of isolated concepts. For this reason, despite that policy elements are considered as transversal keys for implementation purposes at operational level, the complexities in the relations between policy and concept levels are reinforced by this gap. To prevail over these two questions, the solutions have to be operational (in terms of robust monitoring frameworks) and methodological (in terms of accurate contextualization of the policy elements for the knowledge gap overcoming).

The necessity of build a robust monitoring frameworks at context level and a methodological proposal are the core of this paper. In this vein, at assessment level, RRI have built a policy

context in terms of an input–output models [63]. Following this criteria, impacts measurement for both keys for agenda settings and dimensions of the process are subject to be measured by performance indicators divided in process indicators, outcome indicators, and perception indicators. RRI agendas and their deployment were considered as primary general indicator along with the definition of three scopes: performance, perception, and key actors.

In these scopes, performance was dependant of both the processes that promote RRI activities and the effects that these processes own. In addition, performance yields the outcomes, thereby, acting with responsibility was presented as what defines who we are, along with the fact that acting in a certain manner, results in the performance of this action. Responsibility cover perception related with be seen to act responsibly [28]. The definition of perception indicators, needs from the consideration of the key actors. For example, in the case of governance, evaluated in terms of involvement of the wider public in RRI debates, national and supranational governments and stakeholders in science and society can be considered key actors and their interactions, measured for example through social media, can be considered as a perception indicator [28]. A comprehensive step-by-step diagram of the indicators structure to measure the impacts referring to outcomes, processes and perceptions of RRI and monitoring the development of RRI agendas is shown in Figure 3.

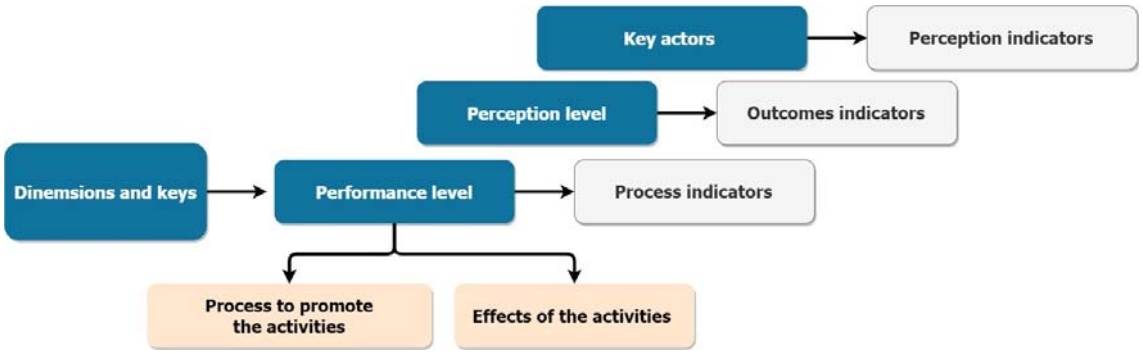

Figure 3. Indicators structure proposal to measure the 'impacts' referring to outcomes, processes and perceptions of RRI and monitoring the development of RRI agendas, based in Strand et al. [28] and the insigths of EU MoRRI project [7].

2.4 Socio-technical integration. Strategies towards transitions

Socio-technical integration is in the foundational backbone of RRI shaping the onset to build the context level. Moreover, its imprint it is recognizable in policy configuration, since it is devoted to scaling the complexity of the issues that involves [71]. This consideration allows to

operationalize the process dimension reformulation and to vertebrate the embracement of alternative approaches such as socio-technical imaginaries and cultural influences. The recognition of these influences allows not only to understanding the concepts and background of the responsible approaches, but also, to appreciate RRI impacts and to arrange the construction of indicators.

Socio-technical theories are being used for policy support in the case of environmental concerns such as climate change, biodiversity and resource depletion. An inclusive vision of socio-technical approaches are socio-technical transitions, which considered sustainability as the engine of change taking into account that how innovations emerge and how they shift and evolve towards this goal are key in the socio-technical transition [72]. These socio-technical approaches, in this environmental context, are often named sustainable transitions entailing, among others, the interrelations between sustainability and social justice under the socio-technical change approaches. Since they share with RRI the idea of scaling the complexity, an integration of this point of view to renewable energy research and innovation yields to consider that the solution to the problems cannot be addressed only through increasing clean technologies needing to incorporate changes or transitions in the system labelled as socio-technical, because they comprise not only new technologies, but also changes in markets, user practices, policy and cultural meanings [73]. These clean technologies include solutions for existing energy, transport, housing and agricultural-food-water systems and need regulations that include investments, behavioural patterns, vested interests, infrastructures, and subsidies.

It is important to point out that despite that socio-technical transition, energy transition and RRI share approaches under socio-technical integration rationales, the approach to the process dimension reformulation differs. In this vein, approaches under transition rationales considered the socio-technical systems approach [74] to define and adjust process dimensions. This approach, which is in the core of sustainable development theories, typify process dimensions as a propriety of the systems. In this vein and for example for sustainability, sustainable development is a property of viable systems and if a system is viable, it will be sustainable. In contrast, the alternative socio-technical imaginaries approaches tackle the visions and understandings of desirable futures of advances in science and technology or technological projects prioritizing the effects of technologies in terms of constriction, provoked reactions from different stakeholder groups, and negative impacts on society [75,76]. This leads to the systems to be placed by the process as it will have developed in further sections.

3. Sustainability assessment approaches

3.1 An overview

Sustainability assessment (SA) is one of the most complex types of monitoring methodologies, due to the fact that not only does entails addressing multidisciplinary aspects of the methods (environmental, economic and social), but also cultural and value-based aspects [36]. SA backgrounds are placed under the impact assessment tradition; policy support methodologies conducted for supporting decision -making; and the strategic environmental assessment.

As mentioned before, these frameworks are recognized by the integration of alternative perspectives and trends. The level of integration results in different integrated assessment frameworks and the sustainability assessment alternatives such as sustainability science which encompasses the integration of concepts such as energy democracy, energy citizenship, new envisions of community energy science and approaches under the umbrella of change. The level of the integration of the frameworks is what gives to this option the consideration of integrated methods and affects also the ingredients comprising sustainability and social justice understandings in terms of new definitions and rationales. However, often the integration threshold is considered not sufficient since even if they assimilate innovative approaches and trends to its formulations, they still acknowledge the inherent conflicts in the pursuit of the sustainable development goals [7].

In the case of alternative sustainability assessment, the frameworks under sustainability transitions approach are considered an example of a new perspective on sustainability studies, focused not on the technological aspects, but on social aspects and the agents behind sustainability [72]. In addition, as a methodology, SA has been tested for the assessment of initiatives such as renewable energy communities and to vertebrate the public involvement in a large spectrum of decision-making processes.

As mentioned in the previous section, in SA frameworks body of works sustainability is scoped regarding to a system in terms of ecological, economic, and social spheres, in contrast with RRI. Since the systems are the places where the innovation process occurs, more than the reformulation of the process, what is ought is to achieve the change in the system. To address these purposes, SA approach is based on the system theory, which monitors the properties of the systems where the development is located. The system theory will be extended in the next section.

The dimensions in SA represent the core of the methodological aspect of these approaches. These dimensions can be grouped in two general divisions: methodological aspects (contexts, discourses, etc.) and the decision making context aspects more devoted to process assessment. Methodological aspects generally cover interactions between economy, society and ecosystems [78] and decision making context aspects comprise, the elements upon sustainability assessment such as policies. In this vein the methodological aspects and the decision making context can be aligned with the process re-envision and the agenda setting process missions of RRI even tough in each frameworks the dimension considerations entails are different.

3.2 Sustainable development models: A systems approach

The sustainable development models come from sustainable development theory [55] used for monitoring sustainability and evaluate the properties of the systems. As mention, these systems are governed by the systems theory and its variations such as the dynamic theory of the systems [47] which are in the core of the sustainable development theories [75]. Sustainable development is an integrative and wide concept, however, it has been dominated by the traditional rationales of sustainability such as the gross domestic product (GDP) and considerations about how the world has measured and understood the progress. In addition, even if the system theory approach provides an important contribution in the measurement of sustainability, its application as an assessment tool yields a series of indicators that provide a partial vision of these dimensions such as states, rates and converters. For example, the indicators monitoring the rates of change of system state are considered the current fuel consumption per minute or food sales per month. Moreover, the indicators providing information obtained by an appropriate conversion of state and rate of information are the average per capital food consumption, computed from total food sales per month and the size of the population.

Since these indicators are not effective in measuring the interactions between all the related dimensions The updates of the sustainable development theory for the broad envision of the systems in terms of socio-technical integration can be considered. It brings, among other advances, the proposal of more accurate multidimensional indicators to measure sustainable energy development [79]. For example, the use of the genuine progress indicator (GPI), which corrects GDP by considering social harms, like the cost of pollution, the cost for households and communities, or the non-traditional concerns regarding the money flows. Another examples of these indicators are the human development indicator (UNDP) or the human scale development indicator (HSDI) which includes, for example, literacy and life expectancy contributing to sustainability [68].

3.2.1 Bellagio STAMP Sustainability Assessment and Measurement Principles

Another important contribution to consider the synergies between sustainability and social justice dimensions are Bellagio STAMP Principles, today renamed as Sustainability Assessment and Measurement Principles, or STAMP. They were formulated to provide guidance for measuring and assessing progress towards sustainable development [35]. In this vein, the principles contribution is related with the acknowledgement of the fact that reformulation of how sustainability is measured requires more than selecting new indicators, technical revisions and reporting mechanisms [80]. The idea behind the Bellagio Principles was related with the fact that harmonization was not simply a matter of selecting common frameworks and indicators, but of following a common approach of developing and using measurement systems as an integral part of the performance of the society and institutions [61].

The Bellagio STAMP principles for sustainability assessment in terms of the *capabilities* regarding progress toward sustainable development and its goals are shown in Table 1.

Table 1. Bellagio STAMP principles for sustainability assessment in terms of the *capabilities* regarding progress toward sustainable development and its goals. Adapted from Bossel [59].

Bellagio STAMP Principle	**Capabilities**	**Elements of SD approach**
Guiding vision and goals	Be guided by a clear vision and goals of SD	Vision and goals
Holistic perspective	Include review of the whole system as well as its parts	Systems approach
	Consider the well-being of social, ecological and economic subsystems, their state as well as the direction and rate of change of the state, of their component parts, and the interaction between parts	Triple bottom line TBL Interactions between elements
	Consider both positive and negative consequences of human activity in a way that reflects the costs and benefits for human and ecological systems, both in monetary and non-monetary terms	Consequences of human activities in terms of costs
Essential elements	Consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use overconsumption and poverty, human rights, and access to services, as appropriate	Resources overconsumption Equity Disparity Poverty Human rights Intergenerational relations
	Consider the ecological conditions on which life depends	Ecological conditions
	Consider economic development and other non-market activities that contribute to human and social well-being	Non marketable economic development: Human and social well being
Adequate scope	Adopt a time horizon long enough to capture both human and ecosystem time scales, responding to current short-term decision-making needs as well as those of future generations	Accurate time scales Long terms outcomes and Short terms decision making needs
	Define the space of study large enough to include not only local but also long distance impacts on people and ecosystem	Accurate space of the study Long term impacts

	Build on historic and current conditions to anticipate future conditions: where we want to go, where we could go.	Background conditions Anticipation
Practical focus	An explicit set of categories or an organizing framework that links vision and goals to indicators and assessment criteria	Vision and goals Indicators Assessment criteria
	A limited number of key issues for analysis	Key issues for analysis
	A limited number of indicators or indicator combinations to provide a clearer signal of progress	Progress Indicators
	Standardizing measurement wherever possible to permit comparison	Standards
	Comparing indicator values to targets, reference values, ranges, thresholds or direction of trends, as appropriate	Thresholds Reference values Performance indicators
Openness	Make the methods and data that are used accessible to all	Open access
	Make explicit all judgments assumptions and uncertainties in data and interpretations	Transparency
Effective communication	Be designed to address the needs of the audience and set of users	Reliability
	Draw from indicators and other tools that are stimulating and serve to engage decision-makers	Engagement
	Aim, from the outset, for simplicity in structure and use of clear and plain language	Accessibility
Broad participation	Obtain broad representation of key grassroots, professional, technical and social groups, including youth, women and indigenous people to ensure recognition of diverse and changing values	Broad participation
	Ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action	Decision makers participation
Ongoing assessment	Develop a capacity for repeated measurement to determine trends	Replicability
	Be iterative, adaptive and responsive to change and uncertainty because systems are complex and change frequently	Adaptation Responsibility
	Adjust goals, framework s and indicators as new insights are gained	Adaptation

	Promote the development of collective learning and feedback to decision-making	Collective learning Feedback to decision-making
Institutional capacity towards assessment process continuity	Clearly assigning responsibility and providing ongoing support in the decision-making process	Responsibility Support to decision making
	Providing institutional capacity for data collection, maintenance and documentation	Data management
	Supporting development of local assessment capacity	Development of local assessment capacity

3.2.2 Sustainable development theory proprieties and orientors

The drivers of the sustainable development theory in terms of systems approach includes, the redefinition of the system in terms of properties and orientors, from which the indicators can be obtained following the theory of the orientor [59]. Orientors represent interests, values, criteria, or objectives, and can be introduced through interdisciplinary approaches and diverse envision of concerns, for example emotions, that can be interpreted as a psychological need as in the human scale development (HSD) approach [81].

Moreover, sustainable development models within the systems approach comprise the recognition and the use of a series of proprieties of the systems which can be considered as impositions of certain requirements and restrictions, which orient system functions [59]. These proprieties can be understood as drivers leading to a series of orientors, due to the fact that the proprieties cause distinct orientation in systems, and orientors represent the systems interests.

These orientors frameworks define normal environmental state, resource scarcity, variety, and variability as the systems proprieties which are connected with the drivers of existence, effectiveness, freedom of action, security, adaptability, coexistence and psychological needs. These proprieties and drivers combination results in orientors of reproduction, psychological needs and responsibility. Proprieties and orientors are interlinked. For example, in the case of resource scarcity and variability properties. In contrast, responsibility, in terms of conscious actors being responsible for their actions and obliged to comply with a normative reference, is considered an orientor.

Moreover, sustainable development models acknowledge the difficulties to define accurate indicators depending to the applications. In these terms, it considers that it is necessary to employ several indicators to cover different aspects of a key or dimension. In these cases, the model proposes the adoption or the construction of a hierarchy to correctly represent different aspects and define the corresponding indicators. The use of this hierarchy is out of the scope of this paper, even though it can be related with the value sensitive design technology assessment (VSD) method under the responsible approach. The crucial point of the process re-envision was considered in terms of the translation of values into design requirements through the integration of a hierarchical structured values [69].

An example of indicators in terms of orientors framework based in sustainable development models and theory can be found in Table 2.

Table 2. Relation between systems properties and indicators for orientators framework based in sustainable development theories. Adapted from Bossel et al. [59].

System performance	Proprieties of the system	Orientator	Possible indicator
Compatibility of the system to exist in a particular environment	Existence	Existence	– Availability of shelter – Clothing, food, water or sanitation – Life expectancy
Efficiency and effectiveness levels	Effectiveness	Effectiveness	– Work force, work hours necessary for life support – Efficiency of resources use
Freedom to respond and react to the needs	Freedom of action	Freedom of action	– Income levels – Job opportunities – Heath – Mobility
Levels of security, safety and stability	Security	Security	– Levels of safety – Savings – Social security scheme – Insurance
Adaptation to changes	Adaptability	Adaptability	– Education – Flexibility – Cultural norms
Level of interactions with subsystems	Coexistence	Coexistence	– Social skills – Compatibility with culture
Level of compatibility with psychological needs and culture	Physiological needs	Physiological needs	– Emotional stress – Anxiety – Dissatisfaction
Level of awareness regarding to the consequences of the actions	Responsibility	Responsibility	– Ethical consideration of the actors

3.3.3 Social sustainability: Frameworks and concepts

An important contribution from SA frameworks to contextualize sustainability and social justice has been the proposal of social sustainability concept and approach, which comprises elements such as social footprint, social impact assessment, or wellbeing [77]. In this vein, Assefa and Frostell [51] proposes a framework to monitor social impacts based on the formulation of indicators of social acceptance of energy technologies [82]. The importance of the systems and their properties, as a final objective to undertake the reformulation of the process, underneath in the definition of social sustainability. Moreover, this approach is also related with the extension of the systems approach in terms of the achievement of an expanded conceptualization of sustainability, including aspects of both coupled systems and dynamical systems theories. All for the purpose of providing an analytical framework for studying mechanisms that enable sustainable development dealing explicitly with conflicting needs and interests among actors in socio–ecological systems [52].

An important contribution of this approach is related with the acknowledgement of the social acceptance concept as one of the basic ingredients of social sustainability. In this vein, and since the systems approach rationale is followed, for a technical system to be deemed socially sustainable it should enjoy from a wide social acceptance. Moreover, socially sustainable systems are characterised by the fairness in distribution and opportunity, endorsed with an adequate provision of social services including health and education, gender and equity. Furthermore, they enjoy from apolitical accountability and they are endowed by participation among stakeholders [51]. In addition, social sustainability framework delves in the understanding of both sustainability and social justice and the importance of the synergies between dimensions leading to the re-envision of concepts such as resilience of the systems which comprise both dimensions insights.

Social sustainability framework includes the processes of analysing, monitoring, and managing intended and unintended social consequences of planned interventions (i.e. policies, programs, plans, and projects), and the social change processes which entails the such interventions evaluation. Moreover, since social acceptance is considered an ingredient of social sustainability, the definition of indicators it is considered the drive to communicate the assessment results. The definition of indicators is framed through the description of a series of social impacts, social aspects, and social indicators. In this vein, the impacts are separated in categories in terms of changes in lifestyle, culture, community cohesion, participation in political decision and governance, environment, health and wellbeing, rights and perception of safety, and future conditions in terms of fears and aspirations. An example of these indicators are knowledge, perception, and fear, which affect the social acceptance dimension not-independently.

Social sustainability as a concept transcends form SA frameworks [83]. In this vein, other definitions of social sustainability are related with the continuation of the society in the future, implying the continuation of its social values, social identities, social relationships, and social institutions, with the social requirements for long-term development, and with concerns regarding with environmental and cultural integration of societies [52].

4. Methodological considerations

4.1 Responsible approach

4.1.1 Outcome based models. An overview

Models to introduce changes in the systems intended to produce outcomes are the essential elements for process assessment. Moreover, in practice, outcomes depend on the interplay between context, design and implementation [84]. The importance of the context and activities for indicators design have been briefly overviewed in the previous sections, with the revision of proposals of generic models. Logic models for the development of assessment frameworks, embedded within a theory of change (ToC), are the most remarkable approaches within the outcome based models [85]. Furthermore, ToC is considered the representation of how and why a complex change process will succeed under specific circumstances and how it can be used for both process and products understanding.

Under the umbrella of the ToC approach, intervention logic models, results based management (RBM) models, realistic evaluation approaches [86], as well as decisions support system approaches can be found. The common components regarding to the structure of the models are the outcomes. In addition, the component of the intervention proposals are the activities leading to the relevant results and the context elements comprising assumptions and rationales. They are also the narratives and contexts, and the system environment [87]. Furthermore, elements of goals, impacts, aims and results are under the outcomes consideration, bearing in mind that they are long-term outcomes.

The expression of the model components, in terms of indicators, is an important aspect of these approaches. In the case of intervention logic model, the context includes the identification and description of key contextual and external factors. These factors influence the intervention either positively or negatively [5], and can be introduced as context description in terms of boundary conditions. These conditions represent external inputs to the methodology, such as values or context indicators which provide information on the environment and overall situation. Most of the theories under the umbrella of ToC recognize the importance of the context to determine the impact of the implemented process. They also consider necessary to understand the interplay between implementation and its effects that operates at social, organizational and individual level.

The intervention logic models have been used in RRI indicators development and policy support [88]. In this vein, since developing an intervention logic model within ToC in RRI approach for

both process and agenda settings provides an opening of the context and outcomes envision, this can help in aligning goals and scopes, enlightening how and why a desired change is expected to happen in a particular context.

At assessment level, the characteristics of the indicators are the following. The input indicators comprise the performed activities, measures taken, structures created and resources allocated. The output indicators are focused in actions addressing the immediate and direct results of activities and outcome indicators are considered long-term achievements and perceived benefits of the changes in systems and policy implementation.

Moreover, the intervention logic model shares with sustainable development models the consideration of perception indicators [89]. This type of indicators is included to measure the fact of be seen acting according to the outcome goals related with certain policy or program, similarly to the case of responsibility as mentioned in the previous section. Furthermore, perception indicators entail the description of the dimensions placed in the interface between R&I and the society. This require from the consideration of insights for actors and action in order to describe the perception by others and by the society in general [57]. An overview of the indicators for the development of outcome base models is shown in Figure 4. where the prevalence in each approach is highlighted.

In addition, these approaches have been used in energy policy re-envisions approaches in terms of decision support system approaches and crowdsourcing innovation approaches [90].

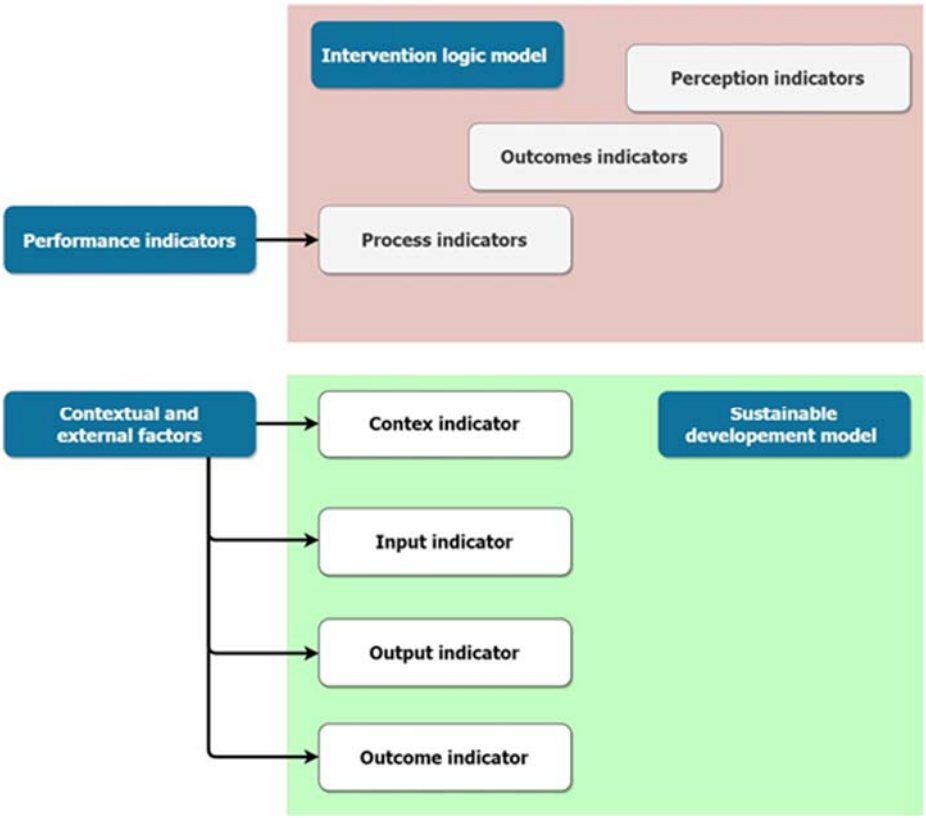

Figure 4. Structure of the indicators considered and its prevalence in the intervention logic model and sustainability development models.

4.1.2 Review of proposals for process dimension assessment following RRI approach

As mentioned in the introduction, the underdevelopments of RRI impacts assessment methodologies [91], the lack of case studies regarding to RRI implementation, along with generalist character of RRI policy [92], makes it difficult to find references in terms of the evaluation systems. In this vein, the recent literature attempting to develop RRI assessment frameworks [17,87,93] indicated that the examples of monitoring the innovation process was mainly carried out through the appraisal of the conceptual dimensions. In this sense, this results in a situation where only the process re-envision mission is amended and the synergies arising from the relations between the two missions and their conceptual and key dimensions are not considered.

For example, Lubberink et al. proposed a model containing a series of elements to describe the inputs, performance and outputs for monitoring innovation process based in responsible innovation and mechanisms for the knowledge-based dynamic capability [17]. In this model, the proposed inputs were The grand challenges (subscribed in the case of the EU in the Charter of Fundamental Rights and Europe 2020 strategy), the uncertainty regarding the innovations future

impacts and the embedding of innovation process in society. Moreover, the elements for evaluating the performance of the innovation process were the assessing alternatives; the reflexion on the effect of the underlying norms, values and beliefs on the innovation at stake, the deliberation with stakeholders about this underlying norms and values, and the adaptation of the results from stakeholder inclusion and deliberation. Furthermore, the approaches to overview the norms were the mentioned basic knowledge [40] enriched by the cultural or societal expectations. Since the rationales of responsible innovation was proposed to guide the methodological process, the use of normative goals was considered for the achievement of the responsibility. This process entails along with the reflexion on activities, the recognition of a commitments and assumptions. Moreover, the responsibility was based in the idea of the pursuit of the broadening moral responsibilities. Regarding the outputs for innovation, the need of societally desirable outcomes, sustainable and ethically acceptable innovations, and the reinforcement of the control and formalization of new and emerging sciences and technologies, was considered. The achievement of anticipation, flexibility, inclusion and deliberation, and responsiveness was proposed to carry out through series of key activities collected in the innovation activities for responsible innovation proposal [17]. The fulfilment of these activities and strategies was considered the operational step towards the achievement of the dimension of process reformulation.

A comprehensive step-by-step diagram of the process reformulation proposed by Lubberink et al. [17] is shown in Figure 5, where the proposed model containing a series of elements to describe the inputs, performance and outputs for assets innovation process based in responsible innovation and the mechanisms for the knowledge-based dynamic capability is described.

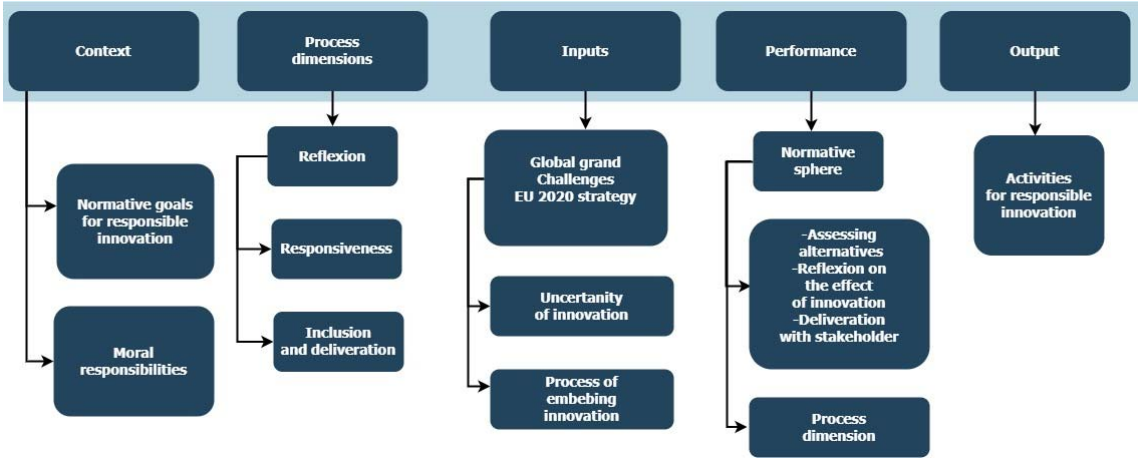

Figure 5. Structure of the model in terms of context, process dimension, inputs, performance and activities. Adapted from Lubberink et al. [17].

Another example of a conceptual model to evaluate the innovation process in terms of outcomes was proposed by Van de Poel et al [87]. This conceptual model was proposed for the development

of strategies for companies based in RRI and corporate social responsibility (CSR) integration. An important contribution of this paper was the specific recognition that both RRI mission were interlinked and should be considered connected.

In this case for developing an RRI strategy, the process dimensions of anticipation, inclusiveness, reflexivity, and responsiveness were taken into account and translated into activities through the use of RRI strategies. This process ought to result in certain outcomes, so RRI key performance indicators (KPI) were proposed to monitor outcomes and progresses. Moreover, the structure of the model included the elements of context, the strategic level, the operational level, and RRI outcomes. Furthermore, the context block included elements such as the type of technology or innovation patters concerns, whereas, the strategy block included the dimensions to follow for the process reformulation. In addition, the activities block included techniques/methods such as scenario building, stakeholders inclusion, and alternative forms of technology assessment such as value sensible design (VSD).

In regards to the key performance indicators, a series of categories was proposed which integrate RRI dimensions and keys and boosted the interlinks between them. For example, the proposals for KPI were diversity & inclusion dimensions for gender equality and engagement; as well as anticipation and reflection dimension of legislative landscape and public and ethical issues. In addition, under the openness and transparency dimension, the intellectual property and confidentiality as well as open access were considered. In the case of responsiveness and adaptive change, both were linked with the keys of environmental sustainability and social sustainability, and were considered as separate elements conforming a category for indicators.

A comprehensive step-by-step diagram of the indicators structure proposal to measure the impacts referring to outcomes, processes and perceptions of RRI proposed by Van De Poel et al. [87] is shown in Figure 6.

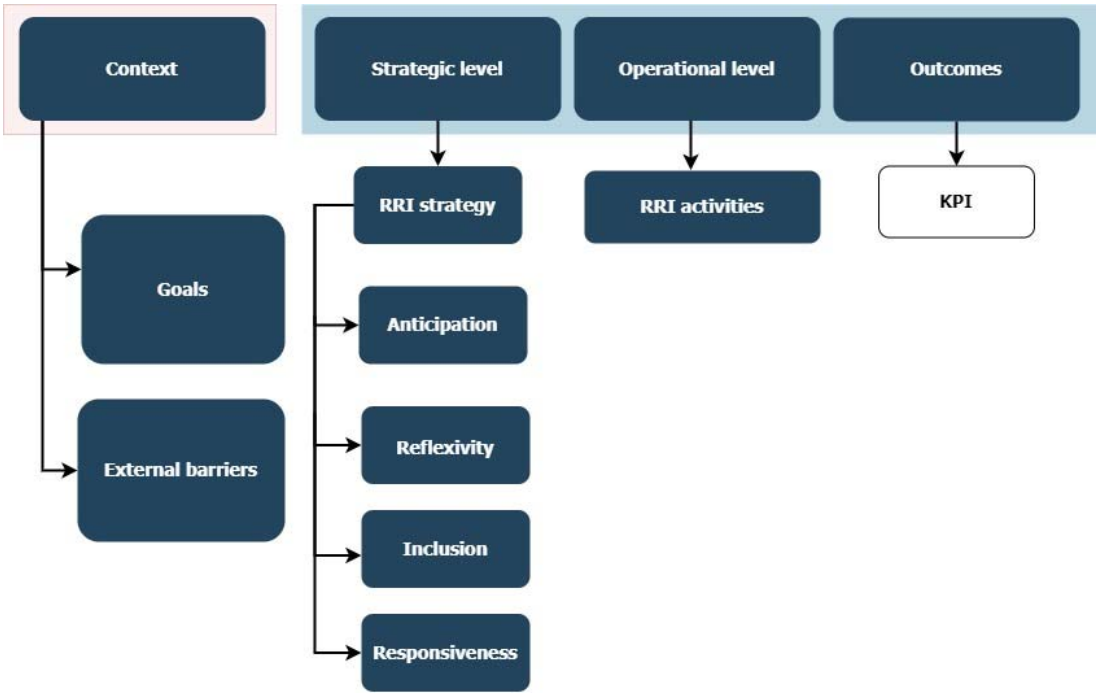

Figure 6. The structure of the model in terms of context, strategic level, operational level, and outcomes. Adapted from Van de Poel et al. [87].

Both Lubberink et al. [17] and Van de Poel et al. [87] models reinforce the idea of the importance of the activities leading to the relevant results. In these terms, an example of activities proposed for the reformulation of the innovation process in terms of anticipation, reflexivity, inclusion and deliberation, and responsiveness conceptual dimensions are show in Table 3.

Table 3. Key activities and strategies proposals for operational appraisal of anticipation, reflexivity, inclusion and responsiveness dimensions of the responsible innovation redefinition process. Adapted from Lubberink et al. [17] and Van de Poel et al. [87].

Dimensions	**Key Activities**	**Techniques**	**Strategies**
Anticipation	Determining desired impacts and outcomes of innovation	Scenario building Foresight studies Technology assessment Life cycle assessment	Monitoring the innovation environment Identifying and understanding societal and/or environmental needs Determining the outputs and impacts Determining the social, environmental and/or economic value
	Preventing or mitigating negative impacts		Monitoring the innovation environment Assessing risks and impact of the innovation Assessment of possible negative consequences of the innovation
	Development of roadmaps for impact		Developing forward and backward scenarios Developing and determining roadmaps Aligning business strategies with the impact vision
Reflexivity	Actions and responsibilities	Codes of conduct Core values Embedded ethicists	Third party critical appraisal inclusion Informal (self-) assessment culture inclusion
	Values and motivations		Prioritization of values and motivations Thinking about the effect of specific values on innovation governance and on its outcome(s) Determining how to deal with incompatible values and/or motivations
	Knowledge and perceived realities		Scrutinizing the presence, absence and subjectivity of information Assessment of the knowledge and abilities Becoming aware of different perceived realities between actors Reframing of problems and solutions
Inclusion and deliberation	Involvement of stakeholders at different stages	Stakeholder mapping strategies Stakeholder engagement strategies Stakeholder dialogues Public dialogues User-centred design	Living lab inclusion Community involvement Focus groups Formal role of the end-user in the company Crowdsourcing Alliances with NGOs Expert involvement for epistemic problems External research and evaluation Multi-stakeholder involvement activities

	Provision of resources and capital	---	Bridging and bonding with experts Official role in firm for users and focus group with wider public Crowdsourcing User-driven innovation Community visiting Representation of stakeholders for anticipation
	Raised commitment and contribution	---	Balancing transparency and openness in relationships and the innovation process Receiving inputs from external actors Fair relationships regarding the tasks and returns for stakeholder input Role recalibrations as roles change over time and need to be readjusted Working with actors sharing the same values Working with actors with different values
Responsiveness	Making sure that one can respond to changes in the environment	Responsiveness to values and needs: – Value sensitive design – Stage-gate approaches – Sustainable design Responsiveness to new developments: – Monitoring – Gradual scaling-up – Adaptive risk management – Living labs and social experimentation – Flexible and adaptive design	Mainstreaming/customizing to satisfy stakeholder needs Prevent or overcome organisational Collaboration for fast and effective response
	Actual response to changing environments		Defining nature, pace and impact based on interactions with the innovation system Changing the environment
	Addressing grand challenges		Responding to social issues Responding to environmental issues Responding to economic issues Preventing detrimental effects
	Mutual responsiveness		Aligning stakeholder interests with the overall innovation objective Investment of resources by involved stakeholders Willingness to recalibrate the roles and responsibilities for sustaining stakeholder relationships

4.2 Methodological aspects of sustainability assessment frameworks

One of the strengths of the body of sustainability assessment frameworks (SA) at methodological and at assessment level lays in its ability for supporting decision-making and policy considering environmental, economic, social context, cultural and value-based elements that transcends the purely technical and scientific evaluation. However, the recognition that SA approach mainly aims to direct decision-making process towards sustainability [35] has raised two important questions about the complexity of the processes shaping the assessment. These questions are the levels of integration and the construction of the dimensions, which are going to be explained in the following subsections and are summarized in Figure 7.

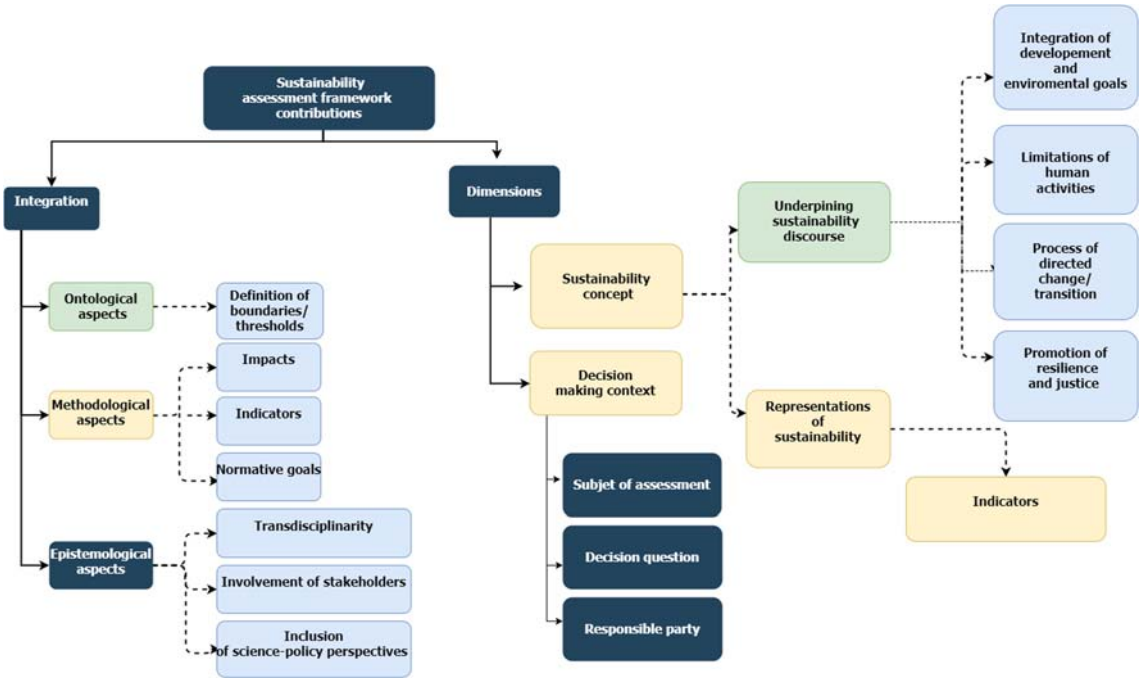

Figure 7. Insights of SA frameworks. Adapted from Pope et al. [35] and Sala et al. [36].

The first question comprises the levels of integration and the different criteria to choose these levels. Even though there is an agreement regarding the levels in terms of ontological, epistemological and methodological levels shaping the integration, there are different criteria to consider the elements comprising the levels. In fact, as mentioned before, the fundamental differences between SA and integrated frameworks are precisely located in these dissimilarities. Moreover, the inclusion of the levels brings the introduction of a series of aspects corresponding to the elements that the framework integrates.

A description of these aspects shows that the ontological aspects calls for comprehensiveness in the assessment in order to define boundaries and thresholds of sustainability. These elements comprise the approach of aspects such as environmental performance, social responsibility and economic contribution, and how the relationships between they diverge from the overlapping to interdependence. Moreover, the methodological aspects generally cover interactions between economy, society and ecosystems [78]. The decision-making context aspects comprise, on the other hand, elements upon sustainability assessment such as policies and responsible parties. Furthermore, epistemological aspects incorporate new perspectives such as collaborative research strategies.

The levels of integration and aspects are important contributions to the assessment process since they provide insigths for a methodological understanding as well as the basis for an indicatorsdesign. In this vein, Sala et al. [36] presented a review of the sustainability assessment methodologies regarding ontology, epistemology and methodology aspects of sustainability in terms of criteria for assesment, methods and outcomes as shown in Table 4.

Table 4. Review of the sustainability asestment methodologies regarding sustainability aspects, namelly ontology, epistemology and methodology. Adapted from Sala et al. [36].

Sustainability aspects	**Criteria for assessment**	**Methods**	**Outcomes**
Ontological	– Sustainability index – Comprehensiveness – Level of integration – Types of covered impact – System boundaries – Scenario developments – Capability to address indirect inputs and effects	– Forward-looking	– Products – Plans – Policies
Epistemological	– Accountability level – Change oriented level – Capability to communicate stakeholders – Interaction level	– Communication – Interaction	– Communication – Public perception
Methodological	– Analytical tools – Procedural tools – Aggregation methods – System boundaries – Data availability – Flexibility – Transparency – Spatial/temporal issues	– Bottom up approaches – Top down approaches – Standardization – Forecasting – Backcasting	– Quantification – Principal component analysis – Modelling

The second question entails the complexity of the dimension consideration. In this sense, whereas RRI is focused in the innovation process re-envisions, SA considers the systems as the major

hypes comprising the assessment process. In this vein, SA builts the dimensions in terms of the systems approach that can be the expresion of the decision-making process or the expression of concepts such as the basic sustainability requirements that should inform a transition to sustainability [94].

Both question about the complexity of the processes shaping the assessment (the integration and the construction of the dimensions) can be considered as criteria to follow when it comes to classifying SA and draw important conclusions regarding to methodological levels and dimension utilities. In this vein, Pope et al. [35] arranged a classification and reconceptualization of SA frameworks taking into account the different aspects of the dimensions within the systems. That study considered that the dimensions of the frames were located under the umbrella of general dimensions of the sustainability concept and the decision-making context. Moreover, this revision considered a series of associated sub-dimensions. In the case of the sustainability concept the sub-dimensions are the underpinning sustainability discourse and the representation of sustainability. And in the case of the decision -making process the sub-dimensions are the subject of assessment, the decision question, and the responsible parties. Furthermore, the sub-dimension of underpinning sustainability discourse comprises the pragmatic integration of development and environmental goals; the idea of limitations on human activities; a process of directed change/transition; and the promotion of resilience and justice [35].

Also, both integration and dimension construction can be considered a contribution of SA frameworks with allows to settle similarities with RRI at methodological level. For example, the methodological level of integration become the SA in a value-laden approach, provided with political character and intimately related to cultural perspectives. For this reason, this approach could be compared with responsible approaches, in terms of values inclusion. Moreover, the decision-making context dimension could be aligned with process re-envision and the agenda setting process of RRI even tough in each frameworks the dimension as a concept entailed a different drive consideration, as mentioned above.

Elements related to the context and assessment can be identified from both the integration and the construction of the dimension branches. For this purpose, in Figure 7 the green and orange colours were proposed for identifying elements regarding to contextualization of sustainability and social justice (green) covering underpinning sustainability discourse and ontological aspects of SA. Moreover, in orange, the elements belonging to the indicators design were considered. In this sense, the branches of sustainability concept proposed from Pope et al. [35] entailing the underpinning sustainability discourse and the representation of sustainability, comprised a series of elements where context for sustainability and social justice underpins. For example, the

sustainability discourse comprised approaches such as the integration of development and environmental goals; the idea of limitations on human activities; the process of directed change or transition; and the promotion of resilience and justice (as shown in Figure 7).Furthermore, the integration of the resilience concept, which was introduced in terms of the ability of the system to maintain functionality, can be considered the ability to maintain the elements needed to renew and reorganise in response to a large perturbation [95]. These understandings of resilience comprise concepts such as restrictions, depletion and inequity in the distribution of resources [96] and elements such as anthropocene, biosphere stewardship, natural capital management, and sustainability sciences applications.

Normative elements, as it happens in another mentioned approaches, are one of the most important dimension of the assessment process. In this case, the normative dimension reflects the underlying concept guiding the process, namely the implicit goal of sustainability. Moreover, the normative discourse of sustainability was located in terms of normative goals, impacts, and undesirable futures. Furthermore, the concepts such as the representation of sustainability, in terms of indicators and how the concept of sustainability is represented in the decision making-process [38], enriched the normative discourse.

The inclusion of these frameworks entails the introduction of other operational elements intended to board the idea of indicators such as principles, drivers, variables, and values. In this vein, it is important to distinguish between sustainability variables (also known as attributes or factors) and sustainability indicators, since the indicators reflect the value of the variables in relation to a defined reference point.

In the case of the indicators proposals, they range from environmental indicators and global and spatial scale indicators for sustainability and corporate sustainability. Sustainability indicators reflected the value of the variables defined for sustainability. In this vein, an example of variables was the triple bottom line (TBL) variables in terms of environmental, social and economic categories. Pope et al. [35] considered the most common variables the TBL variables, the combination of variables beyond environmental, social and economic categories and the variables related with system representations (proprieties).

Moreover, as shown in Figure 7, the decision-making context dimension and its sub dimensions comprise the elements upon general sustainability assessment in terms of policies and plans, projects, etc. and the elements upon who undertakes the assessments, namely regulator and third parties. Furthermore, in the case of decision/question relationship, this can be formulated in terms

of questioning the sufficiency (thresholds), the pertinence of the alternatives (choices), and contribution to sustainability variables.

5. Results: A review of contributions

The purpose of this paper is to illuminate the drivers of the transition from the theoretical discussion to the operational level of a concept for the sake of arranging policy implementation and integration attempts. In the following subsections, the contributions of the reviewed frameworks are going to be threshed following the theoretical considerations exposed in the previous sections. A roadmap of reviewed frameworks following the theoretical frameworks proposal is shown in Figure 8.

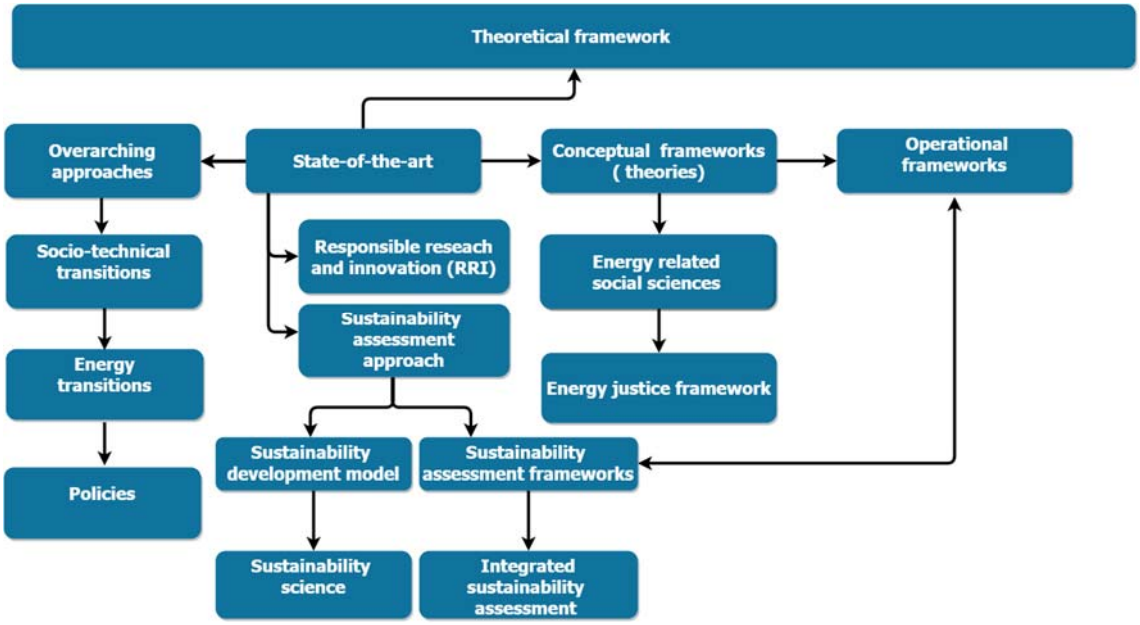

Figure 8. The classification of the contributions of the reviewed frameworks.

The process of measuring the different aspects of the concepts for the contextualization of sustainability and social justice shows that, while, in responsible approaches it aroused as a result of imposing the condition of responsibility on the innovation process, in sustainability assessment frameworks, both keys but specially sustainability are goals to achieve.

In contrast, the process of boarding the concept to embrace different perspectives and trends showed that navigating through sustainability and social justice contextualization and assessment could be framed under different approaches. In the case of socio-technical transitions approaches, the features of how innovations emerged and changed towards sustainability were found as the proposed key for the transition [97]. In the case of the ethics and values representation the

approaches were found devoted to questioning values, background assumptions, and normative orientations in regards to the concerning dimensions of sustainability and social justice. Both socio-technical transitions and ethics approach were found building the background of the collaborative research strategies integration methodologies. These approaches were found being increasingly acknowledged, particularly in the context of transdisciplinary research, aiming to integrate knowledge from various scientific and societal disciplines [98].

In addition, and depending on the approach considered, the proposed levels of context and assessment could be considered separated. But in other cases, the approaches considered a holistic use of the methodologies, where the context and the indicators proposals along with tools on how to carry out the actions are interlinked. For the purpose of the overview of these results, in the cases where concepts and assessment level were found interrelated, the contributions from each frame was highlighted along with the description of the methodological approach and proposals of each framework.

5.1 Responsible Research and innovation RRI

5.1.1 Context contribution

The insights of sustainability and social justice context construction within the RRI policy was found in the 'Science in Society' research policy approaches in the EU [3] as an evaluative element for national research programmes and as a separate priority of climate and environment concerns. Moreover, it was placed comprising different issues such as biodiversity protection, sustainability of agriculture and resources, pollution (air, noise, waste), domestic use of energy, risk management, environmental awareness, and climate variability and predictability [5]. Where sustainability was found framed under the umbrella of risks and sustainability, a category which incorporates matters and criteria related to risk management and sustainable living was found. These approaches transitioned over time towards sustainable development and climate change approaches, which was considered as an indicator for monitoring Horizon 2020 cross-cutting issues. Regarding to RRI and in the goal of the redefinition of the innovation process, social justice underneath in the RRI foundational manifesto [2].

At context level, both sustainability and social justice are in some point related with the fact that the definition of sustainability entails that the satisfaction of immediate needs should not compromise the possibility of future generations to satisfy their needs. This satisfaction in terms of archive sustainability goal comprise also achieving social justice in terms of making

responsible use of resources (achieving responsibility) to ensure the balance between economic growth, environmental care, and social welfare [99].

5.1.2 Assessment contribution

An overview of the policy official metrics regarding to RRI shows that the covered headline target for sustainability was formulated related with the level of investment in R&I as a proportion of EU GDP. Horizon 2020 targeted a mandatory 60% expenditure related to sustainable development. The performance indicators were, defined in terms of their general and specific objectives of the headline, such as secure, clean and efficient energy and other specific priorities. Performance indicators in terms of headline targets were considered, for example, the arranged or planed societal challenges. Also, technical considerations for evaluation, focused on environmental sustainability and environmental impact following the triple bottom line (TBL)were found. In this approach, variables or indicators were separated into environmental, social, and economic in terms of GDP categories.

In contrast, social justice within inclusion was found as a transversal theme running through societal challenges of the Horizon 2020 research programme, which was evaluated, monitoring progress in dimensions of poverty prevention, access to education, labour market inclusion, social cohesion and non-discrimination, health, and intergenerational justice [100]. How social justice was actually addressed through R&I activities was found as discipline under construction, which intended to comprise insights from the consideration of ethical issues and values in the design, development and implementation of new technologies [101].

Moreover, as mentioned previously, the measurement of the extent to which planned programme activities, as well as the contribution of these activities to the headline goals, in terms of sustainability and social justice, was not found directly related with representatives of inclusive or sustainable growth. Process indicators proposed in EU projects for monitoring RRI such as MoRRI [7], which considered indicators in terms of milestones on specified pathways that have an effect on specified dimensions and R&I actors, were found inefficient to offer a guide to describe and evaluate each of the RRI dimensions and keys.

Regarding to the process of RRI indicators development, the methodology of the MoRRI EU funded project was reviewed. This project was aimed to the development of design tools to overcome the knowledge gap between the policy headline targets and the indicators for research and development. Its methodology, based on Kettner et al. [88], proposed a series of outcome, perception and process indicators and other inputs to measure the deployment of RRI.

As mentioned before since policy targets were measured through a societal level of aggregation, and research and development through performance indicators, the correlation of this fact with the indicators proposal was found as the most important burden to overcome.

In the case of sustainability, outcome indicators were defined to monitor the efforts and developments being made towards the expected outcomes. However, this purpose involves the difficulty of not having access to representative data, thus it was proposed to carry out in terms of measuring the milestones on specified pathways of the policy, for example the number of projects with thematic related with sustainable transport, natural resources, global partnership, and good governance. In contrast, sustainability perception indicators were proposed to be answered in terms the anticipated effect of the research projects contributing to sustainable developments and sustainability in general.

In the case of social justice, it was approached in terms of RRI recommendations and within the dimensions of governance and inclusion, which represented the social justice concerns within the responsibility approach. The review proposal shows that social justice process indicators proposal lies in the measurement of the level of relevance, ability and potentiality of new technologies in terms of social justice achievements. For example, the relevance of a new technology or product was proposed to be appraised in terms of the accessibility and the affordability to a wide variety of different social groups. Moreover, the level of ability of the research to address accessibility of a disadvantaged social group, such as disabled people, illiterate people, migrants, and elderly people, or the potentialities of the research project to impact negatively/positively on some social groups was found being an indicator.

Both sustainability and social justice, were proposed to be considered in the context of research activities. These considerations were approached through the perspectives of the relationship between the researchers and the research subjects, and the participation of social groups in benefits arising from research. In this vein, on one hand, the relationship between the researchers and the research subjects was found that comprised, among others issues, the researchers behaviour in terms of taking advantage of research subjects for their own benefit or the benefit of others. On the other hand, in the case of the participation of social groups in benefits arising from research, the potential unfair exclusion of particular groups from either participation in research or accessing to benefits arising from research, was considered. In this vein, these perspectives encourage the equal participation of social groups in benefits arising from research and runs beyond what were found usually included in the ethics approaches and ethics key dimension in RRI.

Due to the influence of this perspectives consideration, outcomes indicators were found to be proposed both in terms of general performance indicators and outcomes indicators related with research activities. These indicators were proposed to be linked with the number of projects where researchers consider the impact of their research on social justice and number of projects where researchers took any steps to either extending the impact of their research to a larger population or to minimizing potential unintended negative consequences in relation to social justice. In contrast, the consideration regarding the percentage of researchers who believe that it was important to consider/address issues related to social justice/inclusion in their research in regards to research methodology and implementation/research results were an example of perception indicators for social justice.

The insights of the indicators proposals are shown in Table 5, where, performance is defined in terms of processes that promote RRI activities and the effects that these processes have, namely the outcome. When taken together, perception and process indicators, they may provide a basis for RRI governance in the sense of improved responsiveness and accountability among R&I actors. Moreover, in the row of concerns, the issues affecting the formulation of the indicators regarding to each key are shown.

Table 5. Insights of the RRI indicators proposal, adapted from [7].

Performance level					**Perception level**
Keys	Process indicators	Outcome indicators	Concerns	Methodologies	Perception indicators
Sustainability	Number of patent, applications or technologies, for mitigation or adaptation against climate change	Number of projects with thematic related with: – sustainable transport – natural resources, – global partnership – good governance	Policy integration issues: – Knowledge gap between the policy headline targets and the indicators for RD – Competence of R&I activities towards address keys (How keys are addressed through R&I activities)	Develop indicators in terms of milestones on specified pathways that have an effect on specified dimensions and R&I actors.	Anticipated effect of a research that contributes to sustainable development. Contribution of anticipated research to sustainability by the use of renewable technologies.
Social justice	Level of relevance, of a new technology/product in terms of accessibility and affordability to wide variety of different social groups. Level of ability of the research problem to address an access problem of a disadvantaged social group, such as disabled people, illiterate people, migrants, and elderly people. Potentialities of the research to impact negatively/positively on some social groups.	General outcomes: Number of projects with a thematic related with: – Poverty prevention – Access to education – Labour market inclusion Social cohesion, and non-discrimination – Health – intergenerational justice Research outcomes: – Number of projects where researchers consider the impact of their research on social justice – Number of projects where researchers took any steps to either extending the impact of their research to a larger population or to minimizing potential unintended negative consequences in relation to social justice	Interrelation and due process issues: – Joint process nature of dimensions and keys – Relationship within the field of research ethics	Develop indicators taking into account RRI backgrounds and interlinks with both keys and dimensions. Outcomes are defined in terms of technologies and social interactions of researchers.	Percentage of researchers who believe that it is important to consider/address issues related to social justice/inclusion in their research in regards to research methodology. Implementation/research results are considered as perception indicators for social justice.

5.2 Energy justice framework

5.2.1 An overview of contributions

The energy justice body of works comprises the envision of central contemporary justice issues arising from the consequences of climate change in the structures of the global energy system, with implications in human dimension and concerns such as happiness, welfare, freedom, and equity [43]. Moreover, at methodological level it is designed to provide a normative and an empirical assessments system of the traditional and new injustices of the low carbon energy transition that under this framework consideration were nuclear waste, involuntary resettlement of populations due to the energy infrastructures, energy pollution, energy poverty, and climate change.

A review of its insights shows that energy justice emerges as a tailored framework to line-up with the two challenges articulated in the sustainable development goals agreed by United Nations, namely the achievement of sustainable low-carbon energy systems and the enhancing of the affordability and equity of new innovations [102]. Both challenges were found related with the concerns of energy policy in terms of sustainable transitions and with the endeavour of responsible research and innovation in terms of the equity of the new innovations.

Following the guidelines to balance the contributions proposed at the beginning of this section, the energy justice framework contributes to characterizing and measuring the different aspects of the concept. Even if this framework advocate for a different responsibility and sustainability dimension consideration regarding responsible approach concerns. For example, in the case of the envisioning of the moral evaluation of technology and systems and the reframing of what technologies are in terms of values [55].

Moreover, contribute to the process of boarding the concept to embrace different perspectives and trends since this approach was designed to provide normative and empirical assessments of both old and new contexts [53].

In this vein, the traditional approaches (in terms of realizing energy projects or implementing energy policies) and contemporary concerns linked with addressing social justice (related with consequences of climate change and the collateral effects in the structures of the global energy system) share a space that can be moreover opened to integrate approaches of community energy, energy democracy, and energy citizenship under the label of energy justice.

5.2.2 Methodological aspects of the energy justice framework: a conceptual, analytical and decision-making tool

Bridging socio-technical and justice aspects is a fundamental concern of sustainable energy transitions approaches, even though, often existing scholars treated both concerns as distinct phenomena [103]. In this vein, energy justice framework, proposed to be used as a conceptual, analytical and decision-making tool has come to be used as a theoretical, policy, political and management methodology [36].

The methodological aspects of energy justice framework can be branched in dimensional an operational feature, as shown in Figure 9. At dimensional level, the framework considers a series of key elements, namely costs, benefits and procedures defined to address the concerns. In this terms, costs are related with how the hazards and externalities of the energy system are imposed on communities unequally, benefits are related with how access to modern energy systems and services are unequal and procedures are related with how many energy projects proceed with exclusionary forms of decision-making [53]. In contrast at operational level, the framework performs as conceptual, analytical and decision-making tool.

The description of the operational features is shown above. In these terms, conceptual utility (in green) of the framework is referred to the multiple function of justice as tool is highlighted in terms of its capacity to link individual wishes to the values of a larger body. Moreover, the usefulness to resolve disputes to extend beyond mere individual preferences along with the capability to enable to make better choices, is important because it distinguishes between outcomes expected from decisions [41]. Furthermore, the conceptual utility comprises the approaches to the tenets of justice in terms of distributional, recognition, procedural, cosmopolitan, and restorative. In contrast, the analytical utility of the energy justice framework (in blue in Figure 9) connects energy policy and technology and it is related with the redefinition of contemporary energy issues using interdisciplinary sources (e.g. philosophical concepts). These principles are virtue, utility, human rights, procedural justice, welfare, freedom, posterity, and responsibility. According to this analytical view, the problem of efficiency becomes reframed not as an economic or technical issue, but one of virtue, and energy poverty becomes immoral because it interferes with human being's ability to achieve functions and capabilities. Moreover, the depletion of resources becomes an issue about present generation versus future generations, and climate change becomes a moral issue concerning responsibility.

As a decision making tool (in orange in Figure 9), energy justice propose the re- envision of this process to promote a series of dimensions namely, availability, affordability, due process, good

governance, sustainability, inter-generational equity, intra-generational equity, and responsibility. The most important insights of this framework regarding sustainability and social justice assessment can be found under the decision making utility and are related with due process consideration and good governance principles. In this vein, due process is defined in terms of stakeholder participation in the energy policymaking process and in terms of the social impact assessments involving community consultation. In the case of good governance, the access to high-quality information about energy and the environment along with the promotion of democratic and transparent decision-making processes within energy governance is considered.

Both responsibility and sustainability considerations for this framework are far from the responsible approach proposed by in RRI. In the case of sustainability, it refers to the duty of sovereign countries to ensure the sustainable use of natural resources and, in the case of responsibility, it includes responsibility of governments to minimize environmental degradation, a responsibility of industrialized countries responsible for climate change to pay to fix the problem (the so-called polluter pays principle), a responsibility of present generations to protect future ones, and a responsibility of humans to recognize the intrinsic value of non-human species, adhering to a sort of environmental ethics [49].

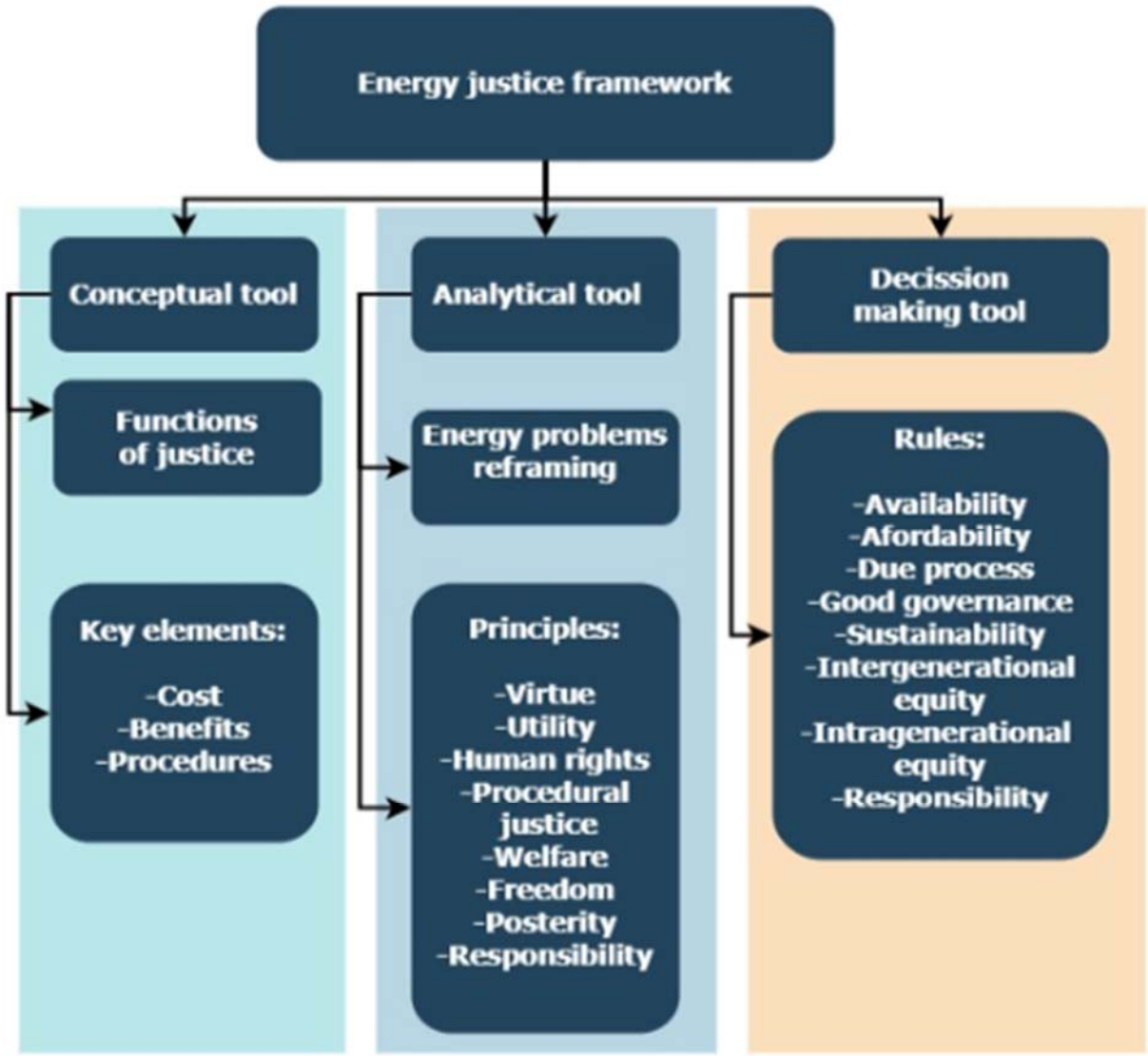

Figure 9. Insights of energy framework. Adapted from [44].

5.3 Sustainability assessment frameworks

5.3.1 A contribution to policy-oriented sustainability assessment

Sustainability assessment approaches are assessment tools used for supporting decision-making and policy development to transit in a broad context which is becoming common practice in product, policy, and institutional evaluation, for example in terms of policy-oriented sustainability assessment. Moreover, they contribute with important insights for pursue sustainability and social justice keys description in terms of descriptive conceptual SA frameworks, integrated SA frameworks and re-envisions evolving towards the integration of elements for the broad and contemporary overcoming of concerns. The contribution of these frameworks can be considered

in terms of the broad understanding of the concepts and its updates integration along with the input in terms of measurement proposals and indicators.

The background overall considerations of sustainability in the approaches that proceed from sustainable development theories have their origin in Brundtland Commission considerations in terms of achieve the development that address the needs of the present without compromising the ability of future generations to meet their own needs [104]. The first approach to integrate new elements for a broad envision of the concepts in SA are the integrated assessment frameworks and the specific descriptive conceptual frameworks which were proposed as an extensions of the concept of the triple bottom line (TBL) [35]. This approach incorporates social and economic considerations to the environmental issues to balance and consider mutual feedback and interactions between environmental and socio-economic systems. Moreover, they introduce the importance of the actors to give equivalence to environmental, social and economic dimensions in decision-making process.

Both integrated assessment and specific descriptive conceptual frameworks provide a more extended vision of the ingredients comprising the process within sustainability. But the grade of integration is based in the acknowledgement of the conflicts in the pursuit of sustainable development goals without taking into account others concerns related with the extension of the frameworks.

In addition, a contemporary review of these alternatives shows that neither offers a full understanding of the complex dynamics involved in the introduction of a new policies nor of an overview of the science–policy and science and decision making interface, especially when conflicting objectives are involved [36], being necessary to envision alternatives to these frames.

In this vein, alternatives such as sustainability science are aligned with RRI in terms of being focused in achieving robust decision-making system changes and dealing with uncertainties. This alignment is reached adopting a holistic approach of policy making, co-production of knowledge, and the embracement of collaborative research strategies. All these elements comprise the aim to transform the innovation process through the steps of research, communication and action.

5.3.2 Specific descriptive conceptual frameworks

Under the umbrella of specific descriptive conceptual frameworks, sustainability is defined as the process to ensure that social and economic issues were covered to an equivalent extent as environmental issues, and where actors are exhorted to adopt a responsible approach and to give

equivalence to environmental, social and economic dimensions in decision-making process [58]. Moreover, in respect of the extension of TBL considerations of sustainability, this approach includes elements of sustainable development goals and models entailing concentric circles or nested egg approaches [105], where the economy is located within society and the environment.

The integration of the development goals, known also as a pragmatic integration, comprises the definition of a series of boundary conditions to acknowledge the conflicts inherent in the pursuit of sustainable development. These conditions are, for example, the limitation of the human activities which are included through the definition of elements such as natural capital that must be preserved, limits of environmental degradation, and the minimum acceptable social limits [35].

5.3.3 Sustainability integrated assessment frameworks

In this case, the extensions of TBL are integrated in terms of the definition of a series of levels, namely ontological, epistemological and methodological levels to vertebrate the integration. The fundamental differences between SA and integrated frameworks are located in the elements comprising the levels. In these terms, the ontological level comprises the boundaries and thresholds of sustainability definitions; methodological level includes the methodologies assisting interactions; and epistemological level entails the shifts and incorporation of new perspectives.

The inclusion of the levels allows to introduce a series of aspects for each level, for example, in the case of the epistemological level, the corresponding aspects are described regarding the new perspectives that can be cultural perspectives and the contribution and involvement of stakeholders in all steps of the process.

5.3.4 Sustainability science

Sustainability science (SS) within sustainability assessment approaches is considered an alternative to the integration of multidisciplinary aspects of sustainability-to cultural and value-based elements. This approach is located under the umbrella of transition approaches in the context where the current global conditions and trajectories lead to an undesirable future, making necessary to reformulate sustainability [38].

As a framework, it is considered an analytical-descriptive tool for system analysis [106] as well as a transformational agenda, addressing the research community needs to complement its historic role in identifying problems of sustainability [107]. Moreover, it comprises problem- and solution-orientated tools that can be considered a holistic approach to problem-solving, based on

a systemic design and mapping of contemporary long-range phenomena, in both the economic and social domains and in environmental, political, and ecological areas.

The holistic approach can be considered from the different perspectives. On one hand as a capability, since the framework operates as a solution-oriented discipline that studies the complex relationship between scientific and social references paradigms [108]. On the other hand, as an integrational approach. For example, in the case of sustainability science, resilience appears as a dimension resulted from sustainability and social justice synergies since sustenance and renewal consideration become obsolete being necessary to include systems disruption and response towards change [107].

In addition, holistic approaches redefine the scope of the frameworks who consider it. In these terms, the sustainability science scope, beyond its application as SA framework, is related with elements from the responsible approach such as dealing with uncertainties. The achievement of this scope is proposed to be carried out through the adoption of holistic approaches and the deployment of social learning and co-production of knowledge. In this vein, the use of collaborative research practices as well as community-based, interactive, or participatory approaches is considered [36]. Moreover, the introduction of collaborative research strategy allows the integration of different methodologies and epistemologies. In this vein, collaboration and participation of different stakeholders, and strong links with the specific social/local context and institutional setting, shape the sustainability problems and the identification of the solutions in terms of subjective and normative dimensions.

The normative considerations are going to comprise the capability to provide direction through visions and goals. This is related with how interlinked human-environment systems would operate and look like if they complied with a variety set of value-laden aims and objectives. Social learning capability is going to entail a mutual feedback leading to co-production of knowledge with other stakeholder groups such as business, politicians, and society in a common process of problem identification and resolution [36].

5.3.5 Methodological framework for sustainability assestment proposal: An innovative framework

The methodological framework for sustainability assessment proposed by Sala et al. [36] entails a reformulation of sustainability assessment in terms of a sustainability science approach which moreover, includes the re-envision of Bellagio STAMP principles from sustainable development models. The framework presented as comprehensive procedural methodology, which overcomes

the reported vagueness and subjectivity in favour of a transparent, robust and flexible assessment. It was developed aligned with the main challenges posed by sustainability science and by the sustainability methods developed in recent years, namely transparency in values and in the choice of analytical tools, robustness in the analytical steps, and flexibility in the decision context of application are all discussed as key elements of the framework.

The drivers of the framework are the principles and procedures adapted from Bellagio STAMP principles from sustainable development models. Under principles, the framework considers values and sustainability principles as preliminary choices in the definition of the sustainability framework on which the assessment will be based. Moreover, an adaptation and update of Bellagio STAMP principles are proposed, highlighting the principle of broad participation with concepts with integrated assessment and sustainability science as well as responsible approach. In this vein, the assessment principles outlined by the research activities are going to be connected with connected with Bellagio STAMP principles which along with the underlying are going to be translate into the implementation of the analytical tools that will be used for the final sustainability assessment. In contrast the procedures comprise several steps based on the integration of sustainability, sustainability targets, the decision-making context, and methodological choices. A schematic representation of the conceptual framework to sustainability assessment is shown in Figure 10.

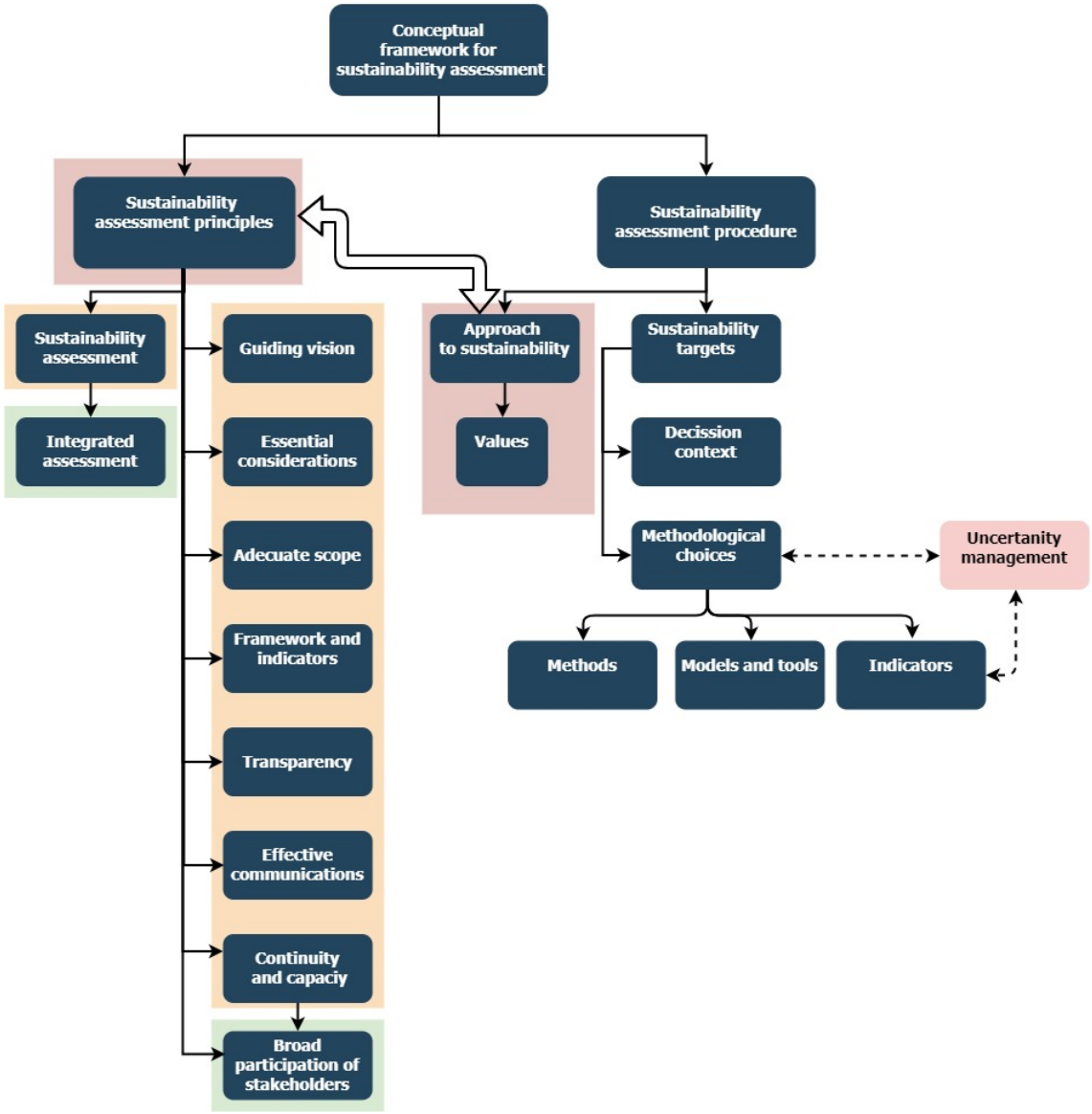

Figure 10. Schematic representation of the conceptual framework for sustainability assessment. Adapted from Sala et al. [36].

An important insight of this framework are the description of the principles and procedures as an integrative element. The inclusion of the principles ensure that what is performed is not just a simple integrated assessment but an effective SA. Moreover, the stakeholder involvement, including the broad participation principle as a specific requirement of sustainability assessment, is considered to be embedded in all steps presented Figure 10. This is proposed following a transdisciplinary setting, leading to a co-production of knowledge from problem definition towards solutions [108].

Moreover, in the approach of sustainability procedure, the values and sustainability principles that together define the sustainability frameworks are located. Furthermore, depending to the elements shaping values and principles, the incorporated perspectives can be classified as an

ecological, economic, eco-economic and public policy-planning theories interpretations or approaches. Sustainability principles in contrast, can be the traditional principles, approached in energy justice frameworks such as precautionary principle, polluters pay principle, intergenerational equity, or good governance comprising also public participation or innovative contributions such as planetary boundaries. Other sources of principles can be considered for example EU Sustainable development strategy and development goals.

In the case of sustainability targets, science and policy based recommendations are located. Moreover, decision context comprises the decision regarding to the subject of decision and how to carry out SA. This assessment can fulfil either through assessing impacts on sustainable development of policies, either through the consideration of the different phases of the assessment along with the approach followed to accomplish assessment approaches that can be based in thresholds approach and scenario planning.

Methodological choices comprise the identification of assessment methodologies in terms of methods, models and tools as shown in Table 5.

The acknowledgement of the complexities regarding the envision of sustainability as a concept as well as the lack of methodologies for its measurement are an important contribution of this framework, although the proposal does not consider separated methodological approaches for both context and assessment levels. In this vein, since sustainability conceptualization and its measurement is observed as a hurdles path, it is considered under an epistemic uncertainty which entails scepticism about the use of the sustainability concept, not only because of its underlying theory, but mainly due to the intrinsic difficulties involved in measuring it.

Regarding context features, this proposal recognizes the richness and complexity of the sustainability concept, which transcends from a disciplinary perspective and expands the subject-object traditional relationship. On the one hand, the commitment of the proposal is reflected in the view of the necessity of defining the sustainability framework, as the rationale and the structure for the integration of concepts, methodologies, methods and tools [109] and in the use of the basic principles for clearly defining *sustainability of what, why and for whom?* [110] before carrying out a SA intervention.

Moreover, it considers new science-society interactions, which lead to multiple forms of knowledge and the synthesis of theory and practice intended to resolve societal problems through collaboration among scientists from different academic disciplines and with other stakeholder groups [111].

In contrast, the conclusion concerning the state of the sustainability assessment proposals leads that on whether empirical examples of sustainability assessment (SA) and integrated assessment are really adequate to evaluate in a solid and reliable manner whether new developments subscribe the Brundtland Commission considerations [104]. In this vein, it considers that the reason why an integrated SA does not meet its objectives, is affected by the fuzziness of the sustainability concept itself. Like social justice, it is a value-laden and has many different dimensions and perceptions [36].

6. Discussion

As exposed, this article is focused in stablishing the methodological basis to arrange a responsible policy integration with the intention of bringing more conceptual clarity to sustainability and social justice dimensions. Its purpose is also the enlightenment of the wealth of material concerning facilitators and inhibitors of this integration.

This process was conducted based in the hypothesis that the insights of the reviewed frameworks can build a methodological approach taking into account that they share a general vision towards achieving, among others goals, the reformulation of the innovation process and the re-envision of the policy agenda setting, as well as the paradigm change in decision-making. Moreover, this hypothesis was ascertained regarding the RRI approach providing a scenario to integrate interactions between renewable energy research and innovation and energy and climate policies.

The discussion of the results of this process was for this reason separated in the challenges for the integration, the identification of facilitator of inhibitors for this integration, and the pertinence of the use of the proposed methodological levels of context and assessment.

6.1 The challenges of integration

RRI approach was found useful to provide a scenario to integrate interactions between renewable energy research and innovation and energy and climate policies since it shares elements with the proposal of a transformative change to overcome the contemporary social and environmental energy challenges. These challenges were considered as the niche where alternative policy approaches could be placed.

The understanding of the missions and the objectives of the policies were found as the first concern of the integration endeavour. In this vein, the integration scenario was found built upon the concepts and understandings of both sustainability and social justice dimensions.

Moreover, the construction of the theoretical framework was based in the necessity to gather the concepts and the understandings, acknowledge the context importance, and overcome the fact that the policy implementation process required shifting from a theoretical discussion to the operational level of a concept. This fact shaped the second consideration of the challenges of the integration since the process of theoretical frameworks construction was carried out in terms of the measurement of the differences aspects of a concept and the embracement of different perspectives. The measurement of the different aspects of the concept was found not entailing additional concern considerations. However, the embracement of different perspectives was found consisting not only in the inclusion of different perspectives, but also in the inclusion of the assessment of the grade or level of integration of the frameworks. Regarding to the level of integration, which indicates the different inputs that, over time, the frameworks were adapting and embodying, was found an important driver for the challenge of policy integration.

This integration level was found useful for gathering the shifts which affects all the reviewed frameworks in terms of perspectives that have been evolving for being affected by new trends. For example, in approaches under the umbrella of energy research and policy, a shift in perspective represented by an integrative view of sustainable development and social sustainability, covering interactions between economy, society and ecosystems, social sustainability, and social justice, was found endowing the approaches with the capability to deal with the complexity of emerging policy issues. An example of the new trends was the emergence of post-normal science, the increasing demand for policy-relevant science, the changes in the development of monitoring, data collection and data sharing mechanisms in terms of citizens participation, along with the proliferation of civil society initiatives regarding governance.

In the case of SA frameworks, the process to integrate alternative elements was found as a consolidated practice yielding emerging holistic approaches such as sustainability science. In this holistic approach, the definition of sustainability was found related with the global awareness of long-term threats to vulnerable ecosystems and with framework operational elements focused in the nature of the problem rather than in the tools and framework capabilities.

6.2 Identification of inhibitors and facilitators: Contribution to reviewed frameworks

The policy implementation was found needing from the identification of a series of drivers, but these elements were found acting either as an inhibitor or a facilitator of policy integration. An important inhibitor, related with the fact that the approaches were intrinsically affected not only

by the meanings, but also by the scope where the action were located (making that the definitions, policy scopes and outcomes were moving from being normative judgments, such as goals and targets, to being a semantic or philosophical concepts) were the different rationales of the approach that appeared when they were applied to different disciplines.

In the case of RRI, even if it was a research policy devised to be applied in any scientific discipline, the application and the rendering of its drivers were found unclear depending on each research field rationale. The different understanding of responsibility, sustainability and social justice for energy research were found affecting the contextualization ,construction of a theoretical framework, and acting as an inhibitor. The underdevelopment of the methodologies was found also as an important inhibitor.

Another inhibitor was related with the fact that both sustainability and social justice dimensions were linked at the context and assessments levels. For example, when sustainability dimension was no longer seen as a goal, but rather how decision-making should contribute to progress along the path to such goal, the dimension transited from context to assessments level. Also, since the systems disruption and response considerations were found shaping the new trends in the approaches, this changed the ingredients of sustainability. For example, while sustainability can be defined, at policy level, more narrowly as the ability of the economy to function within the capacity provided by the earth ecosystems, at context level, it entails that the satisfaction of immediate needs should not compromise the possibility of future generations to satisfy their needs. This satisfaction, in terms of archiving sustainability goal, comprises also achieving social justice in terms of making responsible use of resources (achieving responsibility) to ensure the balance between economic growth, environmental care, and social welfare.

In the case of facilitators, the multiple connections between the two missions of RRI was found as one of the most important strengths of the integration. However, this fact could be considered both a facilitator and an inhibitor. The facilitator effect of the interlinks was related with the sharing of the theoretical backgrounds. This fact allowed to constructed common rationales an overlapping the approaches with responsible innovation. In contrast, the inhibition effect was related with the fact that trapped an absence of consensus regarding to the ingredients that comprise each element was found.

The inhibitor effect of context consideration was found modulated by two factors. The first one was the importance of the context consideration within the intervention. In this case, the proposals based in RRI found in literature, used the normative goals for responsible innovation as well as corporate social responsibility to stablish the context to the achievement of the responsibility.

Moreover, the use of activities for the establishment of the context level was found. The importance of the activities lies in the fact that they come from the interventions proposals, which lead to the relevant results and context elements. Most of the reviewed frameworks considered that the fulfilment of these activities and strategies were considered in the operational step towards the achievement of the dimension of process reformulation.

Furthermore, regarding the use of outcome based models, the reviewed framework shows that the most common assessment frameworks were related with monitoring policy integration carried out by building a framework which evaluates all steps of the process in terms of process, context, performance, and outcomes.

A comparison between intervention logic model used in RRI and sustainable development model showed that the context description can be introduced both through the description of boundary conditions in terms of external inputs to the methodology such as values or through context indicators, or through internal methodological elements defining the approach to be adopted as a key ingredient of the assessment framework.

The second factor was related with the existence of a knowledge gap. This knowledge gap was reified since RRI as a cross-cutting principle throughout Horizon 2020, it was intended to be operationalized through the implementation of an agenda setting dimensions which are related with the headline targets of smart, sustainable and inclusive growth guidelines, but they were not represented by the accurate indicators, since the development for these dimensions cannot be obtained enquiring directly enquiring at what extent does a research field, a research programme or an RRI initiative contribute to these goals, and moreover, how can this be assessed and monitored.

The inhibitor effect of the context was found also affecting SA frameworks. In this vein, , even if an important contribution arising from SA framework review was the acknowledgement of the complexities regarding the envision of sustainability as a concept and its measurement, the questioning process regarding whether examples of sustainability assessment were really adequate to evaluate sustainability remained as important concern. The findings regarding to this concern were related with the fuzziness of the sustainability as a concept and its epistemic uncertainty. The fuzziness of the sustainability concept was shown in its multifaceted nature, which like social justice, was presented as a value-laden with many different sub-dimensions and perceptions. These sub-dimensions were key when it comes to address environmental, economic and social issues and their interactions with robust measures. In the case the epistemic uncertainty

affecting sustainability measurement hurdles path was found related with the scepticism about the use of the sustainability concept, not only because of its underlying theory, but mainly due to the intrinsic difficulties involved in measuring it.

6.3 The pertinence and applicability of methodological levels

The levels of context (considering the context insights along with assumptions) and assessment (entailing the used methodologies, indicators proposals along with tools on how to carry out the actions) were found useful to arrange a methodological basis of an integration proposal. However, in some of the considered approaches, both context and assessment spheres were found interrelated. Moreover, the context level construction shows that this process was built upon the concepts and understandings of both sustainability and social justice dimensions. Furthermore, it was found that it was also affected by the different understanding that for each framework the concerned dimensions had.

In contrast, the assessment level was found strained by factors affecting each framework in terms of policy integration. The review process showed that the level of integration of the frameworks coexist context and assessment levels. This integration can be also considered as a shift whichs affects all the reviewed frameworks in terms of perspectives that have been evolving for being affected by new trends.

The consideration of this grade of integration as an alternative methodological level brings the emergence of other considerations such as the differences between the normative sphere or the conflicts between the understandings as an important insight. For example, the fact that sustainability and social justice were considered in terms of both policy targets and in terms of concepts and the assumption that both *objects* are interrelated emerges as a constraining element as in the case of inhibitors and facilitators of policy integration within the integration levels. As ascertained by the findings of this paper the consideration of this alternative methodological level requires from the re-envisions of the meaning of the normative sphere. For example, in RRI, the normative sphere was built on considering ethical and societal concerns in terms of values giving place to an innovation process reformulation. The outcomes of this endeavour were, the achievement of a democratization of innovation through social, open, participatory, and crowdsourced forms of innovation in order to help to realise a collective responsibility to control and drive innovation into a direction that was considered ethically acceptable, societally desirable, and sustainable. In contrast, in SA frameworks normative elements were found located under the methodological aspects dimensions, where sustainability was placed, along within goals, impacts, undesirable futures, etc. Moreover, this normative sphere was also settled with the representation

of sustainability in terms of indicators of how sustainability was represented in the decision-making process.

The consideration of the levels of integration as a methodological level can be possible if a consensus regarding the normative sphere is taken into account. This can be possible under the looking glass of trans-disciplinarity since it seeks to the integration of different methodologies and epistemologies such as co-production of knowledge in terms of participation of different stakeholders and the inclusion of values. The integration will allow to change the normative sphere, from the dimensions of the systems or process to the identification of the solutions towards achieving strong links with the specific social/local context and institutional setting from where sustainability and social justice issues originate.

7. Conclusions

This paper shows the important challenges to pursue a responsible policy integration regarding the integration of interactions between renewable energy research and energy and climate policies within sustainable transitions. In this vein, the thresholds of this endeavour were detailed along this paper in terms of the challenges for the integration, the identification of the inhibitors, and facilitators of policy integration and the proposal of the levels for a methodology for this integration.

The challenges of the integration, comprised the understanding of the mission and objectives of the policies. Moreover the importance of gaining knowledge about the context within the integration have taken place results in the fact that the context must be considered as part of the validation of the proposed methodology. In contrast, the identification of the facilitators and inhibitors shows that the integration was trapped in the fact that different understanding of responsibility, sustainability and social justice for each specific disciplines was found. In addition, an inhibitor related with the operational level of the frameworks was the fact that each framework has its own driver considerations.

Regarding to the methodological levels proposals, the criteria for ordering contributions in context and assessment brings a valuable source of information, however, the review process showed that these insights could also be considered in terms of the level of integration of the frameworks. The consideration of this alternative level needs from the consensus regarding to the normative sphere, which is possible taking into account the trans-disciplinarity approach.

Finally, since the construction of the theoretical framework was carried out considering the measurement of the differences aspects of a concept and the embracement of different perspectives and even if the reviewed frameworks have binged a detailed vision of the insights for this policy integration, other aspects and frameworks can be considered. In this vein, both paths for the theoretical construction can be enriched by the consideration of the aspects of resilience of the systems which comprise sustainability and social justice insights or the retrieval of the social sustainability within SA related with the pursuit of the properties of the system and the consideration of these, as a final objective to undertake the reformulation of the process. Moreover, approaches and perspectives under transition approach such as energy democracy, energy citizenship or new envisions of community energy science and apart from it can be considered. Furthermore, under transitions approaches the re-envision of the innovation process inspired by responsible approaches can coexist with the system approach, where systems disruption and response along with the reflexion and responsiveness shapes this approach.

Acknowledgements

The work presented was partially funded by the Spanish government (ENE2015-64117-C5-1-R (MINECO/FEDER)). The authors of this paper would like to thank the Catalan Government for the quality accreditation given to their research group (2017 SGR 1537). GREiA is certified agent TECNIO in the category of technology developers from the Government of Catalonia.

References

[1] Stilgoe J, Owen R, Macnaghten P. Developing a framework for responsible innovation. Res Policy 2013;42:1568–80.

[2] Von Schomberg R. A vision of responsible research and innovation. In: Owen, R., Bessant J, Heintz M. (Eds.), Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society. London, UK: Wiley; 2013.

[3] European Commission. Responsible research and innovation. Europe's ability to respond to societal challenges. Brussels, Belgium: 2012.

[4] European Commission. Commission staff working document—Interim evaluation of Horizon 2020—Annex 2. Brussels, Belgium:2017.

[5] Meijer I, Mejlgaard N, Lindner R, Woolley R, Rafols I, Griesler E, Wroblewski A, Buehrer S, Stilgoe J, Tsipouri J, Maroulis N and Peter V. Policy and Research Activities on Science in Society in Europe (MASIS) Final synthesis report. Brussels, Belgium :2012

[6] Lindner R. Monitoring the Evolution and Benefits of Responsible Research and Innovation (MoRRI): Analytical Report on the Dimensions of Research and Innovation Governance. Sub-task 2.5, deliverable D2.4.2. 2015.

[7] Peter V. Monitoring the evolution and benefits of Responsible Research and Innovation in Europe: Summarising insights from the MoRRI project. Brussels,Belgium:2018.

[8] Felt U. Taking European knowledge society seriously. Report of the Expert Group on Science and Governance to the Science, Economy and Society Directorate. Brussels, Belgium:2007.

[9] Cajaiba-Santana G. Social innovation: Moving the field forward. A conceptual framework. Technol Forecast Soc Change 2014;82:42–52.

[10] Directorate-General for Research and Innovation. A contribution to the Open Innovation; Open Science; Open to the World. Science, Research and Innovation performance of the EU. Brussels, Belgium: 2016.

[11] Mejlgaard N, Woolley R, Bloch C, Bührer S, Griessler E, Jäger A, Lindner R, Bargmann Madsen E, Maier F, Meijer I, Peter V, Stilgoe J, Wuketich M. Europe´s plans for responsible science. Science 2018;361(6404);761–2.

[12] European Commission. Horizon Europe—the next research and innovation framework programme. Brussels, Belgium: 2018.

[13] European Commission. LAB – FAB – APP. Investing in the European future we want. Brussels, Belgium:2017.

[14] Mazzucato M. Mission-Oriented in the European Union. Brussels, Belgium:2018.

[15] Ribeiro BE, Smith RDJ, Millar K. A Mobilising Concept? Unpacking Academic Representations of Responsible Research and Innovation. Sci Eng Ethics 2016.

[16] Schot J, Steinmueller WE. Three frames for innovation policy: R&D, systems of innovation and transformative change. Res Policy 2018;47:1554–67.

[17] Lubberink R, Blok V, Ophem JV, Omta O. Lessons for Responsible Innovation in the Business Context : A Systematic Literature Review of Responsible , Social and Sustainable Innovation Practices. Sustainability 2017:9;721

[18] Owen R and Goldberg N. Responsible innovation: A pilot study with the U.K. Engineering and Physical Sciences Research Council. Risk Anal 2010;30:1699–707.

[19] Owen R, Macnaghten P, Stilgoe J. Responsible research and innovation: From science in society to science for society, with society. Sci Public Policy 2012;39:751–60.

[20] Fisher E and Rip A. Responsible Innovation: Multi-Level Dynamics and Soft Intervention Practices. R. Owen, J. Bessant M. Heintz (eds), Responsible Innov. Manag. Responsible Emerg. Sci. Innov. Soc., London: John Wiley and Sons; 2013.

[21] Zhao Y, Zhu Q. Evaluation on crowdsourcing research: Current status and future direction. Inf Syst Front 2014;16:417–34.

[22] Nielsen L, Roure F, Rudze L, Blind K, Guske AL. Options for Strengthening Responsible Research and Innovation: Report of the Expert Group on the State of Art in Europe on Responsible Research and Innovation. Luxembourg, Luxembourg: 2013.

[23] Rodríguez H, Fisher E, Schuurbiers D. Integrating science and society in European Framework Programmes : Trends in project-level solicitations. Res Policy 2013;42:1126–37.

[24] Rodriguez H, Hu M and Fisher E. Socio-Technical Integration in International Research Policy: The situation in the European Union, the United States and China. Engineering and Development in American, Chinese and European Contexts. Dordrecht, Netherlands: Springer; 2012.

[25] Davis M, Laas K. Broader Impacts? or Responsible Research and Innovation A Comparison of Two Criteria for Funding Research in Science and Engineering. Sci Eng Ethics 2014;20:963–83.

[26] Eizagirre A, Rodríguez H, Ibarra A. Politicizing Responsible Innovation : Responsibility Inclusive Governance. Int J Innov Stud 2017;1:20–36.

[27] Oftedal G. The role of philosophy of science in Responsible Research and Innovation (RRI): the case of nanomedicine. Life Sci Soc Policy 2014;10:5.

[28] Strand R, Spaapen J, Bauer MW, Hogan E, Revuelta G, Stagl S and Paula L. Indicators for promoting and monitoring Responsible Research and Innovation. Report from the Expert Group on Policy Indicators for Responsible Research and Innovation. Luxembourg, Luxembourg: 2015.

[29] Meijers E, Stead D. Policy integration in practice The integration of land use planning, transport and environmental policy-making in Denmarkt, England and Germany. Berlin: Delft, Netherlands: Delft University Press; 2004.

[30] Spyridaki NA, Flamos A. A paper trail of evaluation approaches to energy and climate policy interactions. Renew Sustain Energy Rev 2014;40:1090–107.

[31] Carbajo R, Cabeza LF. Renewable energy research and technologies through responsible research and innovation looking glass : Reflexions , theoretical approaches and contemporary discourses. Appl Energy 2018;211:792–808.

[32] Wolsink M. Social acceptance revisited: gaps, questionable trends, and an auspicious perspective. Energy Res Soc Sci 2018;46:287–95.

[33] Upham P, Oltra C, Boso À. Towards a cross-paradigmatic framework of the social acceptance of energy systems. Energy Res Soc Sci 2015;8:100–12.

[34] Wüstenhagen R, Wolsink M, Bürer MJ.Social acceptance of renewable energy innovation: An introduction to the concept. Energy Policy 2007;35:2683–91.

[35] Pope J, Bond A, Hugé J, Morrison-Saunders A. Reconceptualising sustainability assessment. Environ Impact Assess Rev J 2017;62:205–15.

[36] Sala S, Ciuffo B, Nijkamp P. A systemic framework for sustainability assessment. Ecol Econ 2015;119:314–25.

[37] Parris TM KR. Characterizing and measuring sustainable development. Ann Rev Env Resour 2003;28:559–86.

[38] Sachs JD. Social sustainability and whole development: exploring the dimensions of sustainable development. In: E. Becker, T. Jahn (Eds.), Sustainability and the social sciences. New York, USA: Zed Books and UNESCO;1999.

[39] Sovacool BK, Noel L, Orsato RJ. Stretching, embeddedness, and scripts in a sociotechnical transition : Explaining the failure of electric mobility at Better Place (2007 – 2013). Technol Forecast Soc Chang 2017;123:24-34.

[40] Cialdini RB. Crafting normative messages to protect the environment. Curr Dir Psychol Sci 2003;12:105–9.

[41] Sovacool BK, Dworkin MH. Energy justice: Conceptual insights and practical applications. Appl Energy 2015;142:435–44.

[42] García JLS, Sanz JMD. Climate change, ethics and sustainability: An innovative approach. J Innov Knowl 2018;3:70–5.

[43] Jenkins K, McCauley D, Heffron R, Stephan H, Rehner R. Energy justice: A conceptual review. Energy Res Soc Sci 2016;11:174–82.

[44] Forsberg E-M, Shelley-Egan C, Ladikas M, Owen R. Implementing Responsible Research and Innovation in Research Funding and Research Conducting Organisations---What Have We Learned so Far? Gov. Sustain. Responsible Res. Innov. Process. Cases Exp., Cham: Springer International Publishing; 2018, p. 3–11.

[45] Fagerberg J. Mobilizing innovation for sustainability transitions: A comment on transformative innovation policy. Res Policy 2018;47:1568–76.

[46] McCauley D, Ramasar V, Heffron RJ, Sovacool BK, Mebratu D, Mundaca L. Energy justice in the transition to low carbon energy systems: Exploring key themes in interdisciplinary research. Appl Energy 2019;233–234:916–21.

[47] Muench S, Thuss S, Guenther E. What hampers energy system transformations? The case of smart grids. Energy Policy 2014;73:80–92.

[48] Taebi B., Correlje A., Cuppen E. Ethics and impact assessments of large energy projects. 2016 IEEE Int. Symp. Ethics Eng. Sci. Technol., Vancouver, BC: 2016, p. 1–15.

[49] Sheikh NJ, Kocaoglu DF, Lutzenhiser L. Social and political impacts of renewable energy: Literature review. Technol Forecast Soc Change 2016.

[50] Sovacool BK, Ryan SE, Stern PC, Janda K, Rochlin G, Spreng D, Pasqualetti MJ, Wilhite H and Lutzenhiser L. Integrating social science in energy research. Energy Res Soc Sci 2015;6:95–9.

[51] Assefa G, Frostell B. Social sustainability and social acceptance in technology assessment: A case study of energy technologies. Technol Soc 2007;29:63–78.

[52] Sovacool BK, Bazilian M, Toman M. Paradigms and poverty in global energy policy: Research needs for achieving universal energy access. Environ Res Lett 2016;11: (6):4014.

[53] Sovacool BK, Dworkin MH. Energy justice: Conceptual insights and practical applications. Appl Energy 2015;142:435–44.

[54] Pesch U, Correljé A, Cuppen E, Taebi B. Energy justice and controversies: Formal and informal assessment in energy projects. Energy Policy 2017;109:825–34.

[55] Jenkins K, Sovacool BK, McCauley D. Humanizing sociotechnical transitions through energy justice: An ethical framework for global transformative change. Energy Policy 2018;117:66–74. doi:10.1016/j.enpol.2018.02.036.

[56] García JLS, Sanz JMD. Climate change, ethics and sustainability: An innovative approach. J Innov Knowl 2018;3:70–5.

[57] Franceschini S, Faria LGD, Jurowetzki R. Unveiling scientific communities about sustainability and innovation. A bibliometric journey around sustainable terms. J Clean Prod 2016;127:72–83.

[58] Adams R, Jeanrenaud S, Bessant J, Denyer D, Overy P. Sustainability-oriented Innovation: A Systematic Review.International Journal of Management Reviews 2016;18:180–205.

[59] Bossel H. Indicators for sustainable development: Theory, Method, Applications. A Report to the Balaton Group. Winnipeg, Manitoba Canada:International Institute for Sustainable Development; 1999.

[60] Ravetz JR. Post-Normal Science and the complexity of transitions towards sustainability. Ecol Complex 2006;3:275–84.

[61] Pintér L, Hardi P, Martinuzzi A, Hall J. Bellagio STAMP: Principles for sustainability assessment and measurement. Ecol Indic 2012;17:20–8.

[62] Burget M, Bardone E. Definitions and Conceptual Dimensions of Responsible Research and Innovation : A Literature Review. Sci Eng Ethics 2017;23:1–19.

[63] Von Schomberg R. Prospects for technology assessment in a framework of Responsible Research and Innovation. In: Beecroft MD and R, editor. Tech. abschätzen lehren Bild. transdisziplinärer Methode. Wiesbaden, Germany: Springer; 2012, p. 39–61.

[64] Schot J, Rip A. The past and future of constructive technology assessment. Technol Forecast Soc Change 1997;54:251–68.

[65] Fisher, E. and Schuurbiers D. Socio-technical integration research: Collaborative inquiry at the midstream of research and development. N. Doorn, D. Schuurbiers, I. van Poel M.E. Gorman (eds), Early Engagem. new Technol. Open. up Lab. Amsterdam, Netherlands: Springer ;2013, p. 97–110.

[66] Cajaiba-santana G. Social innovation : Moving the field forward . A conceptual framework. Technol Forecast Soc Chang 2014;82:42–51.

[67] Decker M, Weinberger N, Krings B. Imagined technology futures in demand-oriented technology assessment. J Responsible Innov 2017;4:177–96.

[68] Minsch J., Flüeler T., Goldblatt D.L., Spreng D. Lessons for Problem-Solving Energy Research in the Social Sciences. In: Spreng D., Flüeler T., Goldblatt D., Minsch J. (eds) Tackling Long-Term Global Energy Problems. Environment & Policy, vol 52. Dordrecht, Netherlands: Springer;2012.

[69] Correljé A, Cuppen, E, Dignum M. Responsible Innovation in energy projects: Values in the design of technologies, institutions and stakeholder interactions. In: Bert-Jaap Koops. Ilse Oosterlaken, Henny Romijn , Tsjalling Swierstra J van den H, editor. Responsible Innov. 2 Concepts, Approaches, Applications. Dordrecht, Netherlands: Springer;2015, p. 183–201.

[70] REN 21 secretariat. Renewables 2017 global status report 2017.Paris, France: REN 21;2017.

[71] Geels FW. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Res Policy 2010;39:495–510. Unruh GC. Understanding carbon lock-in. Energy Policy 2000;28:817–30.

[72] Dóci G, Vasileiadou E, Petersen AC. Exploring the transition potential of renewable energy communities. Futures 2015;66:85–95.

[73] Unruh GC. Understanding carbon lock-in. Energy Policy 2000;28:817–30.

[74] Hirsch Hadorn G, Bradley D, Pohl C, Rist S, Wiesmann U. Implications of transdisciplinarity for sustainability research. Ecol Econ 2006;60:119–28.

[75] Sovacool BK, Hess DJ. Ordering theories: Typologies and conceptual frameworks for sociotechnical change. Social studies of science 2017;47(5);703-75.

[76] Jasanoff S and Kim J. Dreamscapes of modernity. Sociotechnical imaginaries and the fabrication of power. Chicago, USA: University of Chicago Press; 2015, p. 220–228.

[77] Fisher J, Rucki K. Re-conceptualizing the Science of Sustainability: A Dynamical Systems Approach to Understanding the Nexus of Con fl ict, Development and the Environment 2017;275:267–75.

[78] Hardi, Peter. II. Zdan TJ. Assessing sustainable development.Principles in Practice. Winnipeg, Manitoba, Canada: The International Institute for Sustainable Development; 1997.

[79] Iddrisu I, Bhattacharyya SC. Sustainable Energy Development Index: A multi-dimensional indicator for measuring sustainable energy development. Renew Sustain Energy Rev 2015;50:513–30. doi:10.1016/j.rser.2015.05.032.

[80] Archibald, T., Sharrock, G., Buckley, J., & Cook, N. Assumptions, conjectures, and other miracles: The application of evaluative thinking to theory of change models in community development. Evaluation and Program Planning 2016;59:119-127.

[81] Max-Neef, Manfred A; Antonio Elizalde; Martin Hopenhayn.Human scale development: conception, application and further reflections. New York ,USA: The Apex Press;1991:p. 114.

[82] Miller C, Iles A, Jones CF. The Social Dimensions of Energy Transitions. Sci Cult 2013;22:135–48.

[83] Magis K. Community Resilience: An Indicator of Social Sustainability. Soc Nat Resour 2010;23:401–16.

[84] Wunder S, Brouwer R, Engel S, Ezzine-de-Blas D, Muradian R, Pascual U. From principles to practice in paying for nature's services. Nat Sustain 2018;1:145–50.

[85] Allen W, Cruz J, Warburton B, Allen W. How Decision Support Systems Can Bene fi t from a Theory of Change Approach. Environ Manage 2017:956–65.

[86] Blamey, A. & Mackenzie M. Theories of Change and Realist Evaluation: Peas in a pod or apples and oranges? Evaluation 2007;13:439–55.

[87] Van de Poel I, Asveld L, Flipse S, Klaassen P, Scholten V, Yaghmaei E. A conceptual model Company Strategies for Responsible Research and Innovation (RRI): A Conceptual Model. Sustainability 2017;9:2045.

[88] Kettner C, Kletzan-Slamanig D, Köppl A. Assessing Energy Scenarios for Austria with the ISED-AT Framework. WIFO Work Pap 2015:496;22

[89] Lawrence LM, Kettner MP. Measuring the Performance of Human Service Programs. Thousand Oaks, USA:SAGE Publications; 2009.

[90] Chiu C-M, Liang T-P, Turban E. What can crowdsourcing do for decision support? Decis Support Syst 2014;65:40–9.

[91] Rip A. The clothes of the emperor. An essay on RRI in and around Brussels. J Responsible Innov 2016;3:290–304.

[92] Rip A. The Past and Future of RRI. Life Sci Soc Policy 2014:15.

[93] Flipse SM and Osseweijer P. Improving industrial R & D practices with social and ethical aspects: Aligning key performance indicators with social and ethical aspects in food technology R&D Technol Forecast and Soc Chang 2014;85:185–97.

[94] Schiederig, T., Tietze, F. and Herstatt C. Green innovation in technology and innovation management – an exploratory literature review. R&D Manag 2012;42:180–92.

[95] Walker B, Carpenter S, Anderies J, Abel N, Cumming G, Janssen M, et al. Resilience management in social-ecological systems: a working hypothesis for a participatory approach resilience management in social-ecological systems. Ecol Soc 2015;6:1–16.

[96] Hodbod J, Adger WN. Integrating social-ecological dynamics and resilience into energy systems research. Energy Res Soc Sci 2014;1:226–31.

[97] Dóci G, Vasileiadou E. "Let's do it ourselves" Individual motivations for investing in renewables at community level. Renew Sustain Energy Rev 2015;49:41–50.

[98] Popa F, Guillermin M, Dedeurwaerdere T. A pragmatist approach to transdisciplinarity in sustainability research: From complex systems theory to reflexive science. Futures 2015;65:45–56.

[99] García JLS, Sanz JMD. Climate change, ethics and sustainability: An innovative approach. J Innov Knowl 2018;3:70–5.

[100] OECD. Social justice in the OECD — How do the member states compare? Sustainable governance indicators. Gütersloh, Germany: Bertelsmann Stiftung;2011.

[101] Van de Poel I, Fahlquist JN, Doorn N, Zwart S, Royakkers L. The Problem of Many Hands: Climate Change as an Example. Sci Eng Ethics 2012;18:49–67.

[102] United Nations. Sustainable Development Goals 2012 and The Millennium Development Goals Report 2012.
http://www.undp.org/content/undp/en/home/sustainable-development-goals.html.
[accessed December 8, 2017].

[103] Sareen S, Haarstad H. Bridging socio-technical and justice aspects of sustainable energy transitions. Appl Energy 2018;228:624–32.

[104] Brundtland GH. Report of the World Commission on Environment and Development: Our Common Future. New York, USA: United Nations ;1987.

[105] Keiner M. Re-emphasizing sustainable development – the concept of evolutionability. Environment, Development and Sustainability 2004;6: 379–392.

[106] Turner BL, Kasperson RE, Matson PA, McCarthy JJ, Corell RW, Christensen L, et al. A framework for vulnerability analysis in sustainability science. Proc Natl Acad Sci 2003;100:8074–9.

[107] Clark WC, Dickson NM. Sustainability science: The emerging research program. Proc Natl Acad Sci 2003;100:8059–61.

[108] Osorio LAR, Lobato MO, Castillo XÁ Del. An epistemology for sustainability science: a proposal for the study of the health/disease phenomenon. Int J Sustain Dev World Ecol 2009;16:48–60.

[109] O'Connor M. Deliberative Sustainability Assessment: Multiple Scales, Multiple Stakeholders, Multidisciplinarity and Multiple Bottom Lines; Methodological Study for Work Package WP6 of the SRDTOOLS Project (Methods and tools for evaluating the impact

of cohesion policies on sustainable regional development, EC 6th Framework Programme, Contract No.502485, 2005-2006). Research report. St-Quentin-en Yvelines, France, Université de Versailles St-Quentin-en Yvelines; 2010.

[110] O'Connor M. Paradigms for sustainability assessment: Inventory of cost and benefits versus representative diversity of indicators. Background Paper in Support of the United Nations System of Environmental-Economic Accounts (SEEA) 2010 Reform Process 2007

[111] Sala S, Farioli F, Zamagni A. Progress in sustainability science: Lessons learnt from current methodologies for sustainability assessment: Part 1. Int J Life Cycle Assess 2013;18.